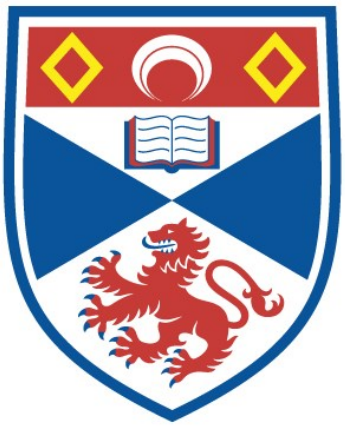
CEREBRAL HEMISPHERIC STUDIES ON THE VISUAL PERCEPTION OF MOTION

Alexander Mackenzie

A Thesis Submitted for the Degree of PhD
at the
University of St Andrews



1981

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by

Alexander Mackenzie

Doctor of Philosophy
University of St. Anderews
~~October 1980~~
MARCH, 1981

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Acknowledgements

I wish to express my thanks to

David Milner and Brian Rogers, my supervisors, for guidance, friendship, and patience.

Frank Funderburk for assistance with statistical analyses.

And the "volunteers" who participated as experimental subjects.

Abstract

Experiments were conducted to examine the differential capabilities of the cerebral hemispheres for the visual perception of motion.

Subjects were normal right handed adult male and female humans.

Stimuli were viewed binocularly and responses were manual in all studies.

Lateralized low contrast real motion was presented using random texture patterns. The task was to correctly detect the direction of motion. The outcome was a significant hemisphere x trials interaction. The right hemisphere improved significantly over trials while the left hemisphere did not.

Using random texture patterns in which a small lateralized square was presented in apparent motion, hemispheric superiorities were found to depend on fairly basic stimulus parameters. For low contrast relatively long stimulus field durations, the right hemisphere was significantly superior. For higher contrast apparent motion stimuli with a "masking" ISI, the left hemisphere was significantly better at accurately detecting the direction of motion.

V shaped stimuli may be presented in apparent motion so as to be seen as either moving within the stimulus plane, or rotating in depth outside it. The percentage of "space" (i.e., rotation) responses increases as the ISI is lengthened.

The hemispheres did not differ significantly in their judgments of motion in depth, therefore, they appear to be employing identically calibrated detection mechanisms. However, female right hemisphere "space" responses remained constant over trials, while analogous male responses decreased linearly.

Stimulus parameters which had been shown in earlier experiments to result in hemispheric differences were avoided, and subjects required to identify apparently moving shapes in a random texture background. No hemispheric differences were observed in this detection task.

An additional finding was that female subjects tend to more frequently report that sub-vocal verbalization mediated their (manual) responses.

Table of Contents

Chapter 1

Introduction and Literature Review

Language

It is now widely accepted that the cerebral hemispheres of the majority of intact adult humans differ in the functions which they optimally perform. The difference is clearest for language and this was the disparity first noted.

Dax (1836) reported that aphasia was typically associated with injury to the left cerebral hemisphere, and Broca (1865) independently came to the same conclusion, localizing motor aphasia in the posterior third of the left frontal gyrus (Broca's area). In 1874, Wernicke, again on the basis of cerebral lesions, suggested the posterior third of the left superior temporal gyrus (Wernicke's area) as the center for the comprehension of spoken language. In addition, Broca recognized that in certain left handed patients, aphasia resulted from damage to the right hemisphere, as did Jackson (1868).

These and subsequent findings led to the view that in right handed people, language was localized in the left hemisphere, whereas in left handers it was localized in the right hemisphere. It is now clear that this is not the case [Ettlinger et al. (1956), lesion studies; Wada and Rasmussen (1960), injections of sodium amytal into the cartoid artery; Milner et al. (1963), sodium amytal;

Hecaen and Piercy (1956), focal epilepsy studies; Hecaen and DeAjuriaguerra (1964), lesion studies of left handed subjects; and Roberts (1969), literature review]. These clinical studies indicate that over 90% of right handers are left hemisphere dominant for language, and that between 60% and 70% of left handers and ambidextrous patients are also left hemisphered for language. For the remainder, language is localized either in the right hemisphere, or is bilaterally represented. These percentages apply to patients with no recorded history of early left hemisphere damage. In cases where there is such a history, a shift of language to the right hemisphere is likely. However, since the populations in these studies were clinically brain damaged, it is possible that the percentages with right hemisphere or bilateral language are elevated relative to a "normal" population. This may be especially the case for the left handers and the ambidextrous.

In dichotic listening tasks the subject receives, to different ears, simultaneous competing messages which are played via stereo headphones. The subject is required to recall or report what has been presented. Physiological evidence indicates that the sensory pathways are superior between an ear and the contralateral hemisphere. Consequently, ear differences in the number of items correctly reported are usually interpreted as reflecting differences in hemispheric competence.

Kimura (1961a) dichotically presented digits to patients with left and right temporal lobe lesions. She found that those with left temporal lesions reported fewer correct than the right temporal group, and that after an operation on the affected lobe, the difference was increased, i.e., scores fell significantly for removal of part of the left temporal lobe, but not for an analogous intervention on the right. Also, pre operatively, digits presented to the right ear were more accurately reported by both patient groups. This right ear effect was confirmed for normal subjects (Kimura, 1961b). In the patients, a sodium amytal test of language locus significantly predicted the superior ear for both left and right hemisphere language dominant subjects.

Curry (1967) reported right ear superiority for real or nonsense words for his right handed subjects, but only real word right ear superiority for his left handed subjects. Zurif and Bryden (1969) found a right ear superiority for digit report for right handers and non-familial left handers, but no difference for familial left handers.

Satz et al (1967) found that on tests of manual strength and dexterity, self classified "left handers" were a heterogeneous group, showing left, right or no hand superiority on the manual tasks. The "right handers," by contrast, scored better on the majority of tasks with their right hand. On the dichotic listening task, the

right ear gave better scores for the majority of "right handers," and for the majority of "left handers" who were classified as right handed or ambidextrous on the basis of manual tests. However, of the strongly left handed "left handers," around 60% were right ear superior and 40% left ear superior.

In summary, dichotic listening experiments are good, but not perfect, predictors of hemispheric language dominance as measured by the sodium amytal test. Normal subjects when dichotically presented language stimuli tend to show right ear (therefore left hemisphere) superiority. The results are more clear cut for right handers than for left handers, with familial left handers giving a more balanced distribution of ear superiority.

Visual stimuli may be selectively directed to a particular cerebral hemisphere by briefly presenting a stimulus in a precise area of the visual field. In practice, this is usually accomplished using a tachistoscope. With the subject fixating on a central spot, stimuli which are flashed up at sufficient displacements to the left or right of fixation are available initially only to the contralateral cerebral hemisphere. This will be discussed in detail in Chapter two, but here it should be taken that stimuli presented in the <u>left</u> visual field (LVF) go initially to the <u>right</u> hemisphere for processing, and <u>right</u> visual field (RVF) stimuli go to the <u>left</u> hemisphere. In a normal subject

the information may then be transferred via the corpus callosum to the other hemisphere. However, the initially recipient hemisphere makes the first processing decisions regarding the stimulus.

Results from experiments involving normal subjects in which single letters, sets of letters, or words are tachistoscopically presented laterally from fixation, cannot be unequivocably interpreted as showing left hemisphere superiority for language.

Presumably one would expect better recall or recognition for RVF letters or words, but this is not always observed. Since the initial work of La Grone (1942), Mishkin and Forgays (1952) and Heron (1957), a plethora of experiments have been conducted giving a variety of results. The most common interpretations of the data are: learned reading habits, scanning a memory trace, cerebral dominance, or interactive effects of these. This work has been critically reviewed by White (1969, 1972, 1973) and Harcum (1978). Typically, but with noteworthy exceptions, e.g., McKeever and Huling (1971a, 1971b), bilateral presentations (in which stimuli are presented simultaneously on each side of fixation) result in LVF superiority; whereas unilateral presentations (with stimuli on only one side of fixation for a particular presentation) tend to result in RVF superiority. Further, these visual field differences may be suppressed or reversed by experimental manipulations such as changing

the language (e.g., with Yiddish), manipulating the stimuli (e.g., using mirror images), or requesting a particular order of report.

Tachistoscopic studies of "split brained" patients, in whom the cerebral hemispheres are surgically separated by cutting the corpus callosum, revealed complete language comprehension and response by the left hemisphere. The right hemisphere was incapable of spoken or written verbal output. Techniques which permitted the right hemisphere alternative means of communication revealed in some patients verbal comprehension in the right hemisphere. If for example a noun was flashed up tachistoscopically in the LVF (to the disconnected right hemisphere), the subject could retrieve, using his left hand and therefore his right hemisphere, the named object from an unseen array. To check whether the left hemisphere had been involved in the choice, the subject would then be asked to name the still unseen object, whereupon the left hemisphere would confabulate a guess (Gazzaniga & Sperry, 1967).

This right hemisphere verbal ability seemed to be limited to simpler nouns. Subjects were incapable of carrying out simple LVF printed verbal commands such as "tap," "smile," etc. (Gazzaniga, 1970). In further studies, Gazzaniga and Hillyard (1971), the right hemisphere seemed incapable of distinguishing singluar from plural nouns, but could distinguish affirmative from

negative verbs, e.g., "sitting" from "not sitting." In the latter tasks a picture would be flashed up, and the subject had to choose the correct description of the depicted scene from two spoken alternatives.

Zaidel (1977) fitted similar patients with a contact lens system which confined the visual input to one hemisphere, and therefore permitted extended visual scanning of the stimuli. Thus equipped, patients were verbally requested to perform relational manipulations of plastic "tokens" which varied in shape, size and colour. Zaidel reported that "the right hemisphere can comprehend size adjectives, color adjectives, and shape nouns when they are presented in isolation with a small choice array, but their combination in adjectival modifying phrases of the form 'the large green square,' causes constant right hemisphere errors." This deficit he ascribes to "a limitation in short term sequential verbal memory." There were no significant differences betrween the subjects' left hemisphere scores on the task and scores under free vision.

The preceding is a brief overview of the differences between the cerebral hemispheres in verbal competence, and the use of handedness as a predictor of linguistic superiority. The experiments to be reported in this thesis are visuo-spatial in nature, so the remainder of the review will concentrate on such hemispheric differences. However, with human subjects, even when they

are performing purely visuo-spatial tasks, the possibility of language mediation cannot be ignored.

Clinical Reports A: Visual Impairment due to Brain Lesion

In 1876, Jackson described a case which he termed partial "imperception." The patient became suddenly lost near her home, and thereafter would do peculiar things such as put her clothes on backwards. She also began to make mistakes about the identities of people she knew. Subsequent autopsy revealed tumors of the right temporo-occipital region.

The diagnostic terminology applied to such syndromes has changed, progressed and regressed in the ensuing century or so during which cases have been studied. Different writers frequently applied the same name, e.g., agnosia, to different sets of symptoms. The early general catchall appears to have been "mind blindness," whereas now "visual agnosia," frequently qualified by additional adjectives or nouns, is used.

Freud (1891) suggested the term "agnosia" as a replacement for such earlier usages as "asymbolia." In 1900, Liepmann differentiated between agnosia and apraxia to separate disorders of motor activity, apraxia, from sensory defects, agnosia.

Kleist (1912) distinguished motor and ideomotor apraxia from constructional apraxia, the latter being a disorder of movements under visual control. Constructional apraxia is the term currently commonly used to describe the behavioural deficits observed in patients

with a primary diagnosis of visual-spatial agnosia. That is the failure to draw an adequate copy of a simple geometrical figure or to arrange blocks matching a sample, as a result of an inability to process visual information. That the decrement is basically visual may be determined by the patient's response to visual stimuli. For example, he may be unable to recognize a cup visually, but when it is handed to him, he immediately knows that he is holding a cup and what its function is (Macewen, 1893).

Decrements of this type are observed in their severest form as a result of bilateral lesions and it is with such cases that early writers were most familiar. Gowers (1888) wrote, "The structures that subserve the functions lost in mindblindness are certainly separate from those of the half vision centers, since hemianopia from disease of the cortex does not necessarily involve this special loss. The centres concerned are probably in front of the half vision region, either in the anterior part of the occipital lobes or in the posterior part of the parietal lobes. The latter is more probable....We do not know whether complete mind blindness can be produced by a lesion in one hemisphere, or whether disease of both hemispheres is necessary for the production of the symptom."

However, by the turn of the century, Mills (1898) indicates that it was beginning to be accepted that "mind blindness" could result from unilateral lesions.

Head's (1926) studies were mainly concerned with the left hemisphere and consequently his reports tended to emphasize its role in object agnosia.

Nielsen (1937) reviewed the case reports published up to that date, selecting only those in which visual agnosia for objects arose from unilateral lesions. He concluded:

"1. One occipital lobe is dominant over the other for recognition of objects.

"2. The dominant lobe is usually the left but may be the right, even in right handed persons."

Paterson and Zangwill (1944) describe two cases of right parieto-occipital injury. These cases exhibited a neglect of the left half of visual space, and in drawing there was a tendency to shift the perspective and orientation of the sketched object. One patient over estimated the distance of things at 250 mm and under estimated their distance at 1,000 mm in the left field. Dots tachistoscopically presented in central vision could be reproduced if they were arranged in regular groups but not if they were presented in irregular configurations.

McFie et al (1950) report 8 cases of right occipito-parietal lesions. The authors stress these patients' neglect for the left side of visual space, the upset of drawing and copying abilities and severe deficits on Kohs' Blocks. Ettlinger et al. (1957) report 10 further cases with right posterior cerebral damage. These patients exhibited similar deficiencies.

It should also be noted that dressing apraxia is frequently observed in patients with right occipito-parietal lesions. According to Hecaen et al. (1956), "The apraxia for dressing is met with only in right sided lesions." But it may occasionally be encountered in left sided injury (McFie and Zangwill, 1960; Hecaen, 1962).

Piercy et al (1960) reviewed their hospital records for cases of unilateral lesion and found constructional apraxia occurred twice as frequently in right hemisphere lesions as compared with left hemisphere lesions. In the right handed patients selected for particular scrutiny, more frequent drawing and constructional test detriments were observed for the right hemisphere cases. In copying a drawing of a house, the left hemisphere damaged patients were superior, whereas in spontaneous drawing, there was no clear difference between the groups. Unilateral neglect was also more frequent in the right hemisphere lesioned group.

McFie and Zangwill (1960) studied left hemisphere parietal and occipital lesions in right handed patients. They compared the deficits of these patients with those of right hemisphere damaged cases that they reported earlier. They state, "In contrast to previously described groups with right-sided lesions, the disability in this group was rarely associated with unilateral neglect, apraxia for dressing, or failure on tests involving spatial analysis,

including topographical memory, but was frequently associated with right-left disorientation and general intellectual impairment, including failure on a sorting test, with which the group with right-sided lesions had little difficulty."

Hecaen (1969) reports the rates which he and his coworkers, DeAjuriaguerra et al (1960), have observed constructional apraxia:

"93 times in 151 right sided lesions (61.58%)

82 times in 206 left sided lesions (39.8%)

40 times in 54 bilateral lesions (74.07%)"

Warrington et al. (1966) compared patients with left and right cerebral damage. The two groups did not differ in drawing disability for copying or freehand drawings, as rated on a number of criteria by an independent judge. The subtler differences which were observed led Warrington et al. to the conclusion, "The types of error made by patients with right hemisphere lesions suggest that these patients have difficulty in incorporating spatial information into their drawing performance, leading to disproportion and faulty articulation of parts of the drawing, while patients with left hemisphere lesions seemed to experience difficulty in planning the drawing process, leading to simplified versions of the model."

Clinical Reports B: Spatial disorientation

A symptom often observed in conjunction with visual agnosia is topographical disorientation. Holmes (1919) reports eight cases of gunshot wounds to "the posterior

and upper parts of both parietal lobes." These patients had great difficulty in learning their way about the ward. They would walk into objects and set off in the wrong direction when attempting to go to a visible goal. In addition, they seemed to be able to "see" only one object at a time.

Brain (1941) differentiates cases suffering from a loss of topographical memory or an inability to describe familiar routes, from patients who lose their way due to always turning right rather than left. The latter symptom he ascribes to left homonymous hemianopia resulting in left hemi-inattention. He describes three cases due to lesions of the right parieto occipital region.

Paterson and Zangwill's (1944) right parieto-occipital injured patients were unable to draw a plan of their ward or house. Neither were Head's (1926) left hemisphere lesioned "semantic aphasia" cases who also had considerable left-right confusion.

In their 1945 paper, Paterson and Zangwill review earlier cases of loss of topographical memory and disorders of spatial orientation. They recall Jackson's 1876 case, and note that Meyer's (1900) patients did not display concommitant visual agnosia for objects, but all had hemianopia. The case which Paterson and Zangwill (1945) describe had fairly severe symptoms as a result of a right parietal wound. Other cases usually exhibit a subset of the detriments observed in this patient. He had

great difficulty finding his way around the hospital due to his right turning tendency, and his inability to recognize rooms. He failed to correctly identify landmarks in his home city and was disoriented with regard to their geographical relationships. He could not draw an accurate plan of his house or correctly locate places on an outline map. His drawing, copying, and constructional skills were disorganized. He neglected the left half of visual space and had dressing apraxia. He would also vastly overestimate the passage of time and the distance he had traveled in his wheelchair. This latter distortion of time and space is also remarked upon by Luria (1973, Chapter 5) in cases of right hemisphere lesions.

Comparing McFie et al's (1950) eight patients, all of whom had right occipito-parietal injury, with their group of eight with similar left sided lesions, McFie and Zangwill (1960), reveals an interesting difference. In the right hemisphere injured group, five had episodic loss of topographical orientation whereas this was observed in only one of the left hemisphere group.

Clinical Reports C: Distortions of depth perception

As noted earlier, one of Paterson and Zangwill's (1944) patients had difficulty judging depth. Holmes (1919) discusses his eight bilaterally parietally wounded cases. They were unable to accurately judge the distance of a building, or reach precisely for an object unless it was touching some part of their body. They could not judge which of two objects was further away, nor could

they decide which of two objects was larger unless they were familiar with them. Also to one of the patients, three dimensional objects appeared flat.

One of Riddoch's (1917) patients exhibited the same extreme symptoms. This man was bilaterally injured but the damage to the right hemisphere was clearly more extensive.

Riddoch (1935) reports two further cases of left parietal lobe tumors. These patients were unable to accurately locate objects in depth in the right visual field. However central vision with fixation was retained, and "stereoscopic vision was intact."

Brain (1941) discusses a case of left parietal, a case of right parietal and a case of right temporal damage. All had difficulty localizing objects in depth in the visual half field contralateral to their injury.

The ensuing literature in the field indicates that bilateral lesions predominate in reports of loss or upset of depth perception. For unilateral damage, the right hemisphere is more frequently implicated (Danta et al, 1978).

While depth perception is clearly not limited to stereoscopic information, Gibson (1950), random dot stereograms, Julesz (1971), provide a means of examining depth perception in the absence of monocular shape and depth cues. Carmon and Bechtoldt (1969) found right hemisphere lesioned subjects to be significantly worse

than left hemisphere lesioned or non injured controlls in detecting stereoscopic squares in random letter patterns. Similar results were obtained by Benton and Hecaen (1970). These findings were interpreted as demonstrating a right hemisphere superiority for stereopsis. Using more standard tests, Rothstein and Sacks (1972) found a greater impairment for left parietal lobe damage, and Lehmann and Walchli (1975) found no difference between their patient groups. Hamsher (1978) compared patients on the random letter (Julesz) task and two standard tests of stereopsis. He found no difference for the standard tests, but marked deficits for the right hemisphere group for the Julesz test. Danta et al (1978), in two tasks, haploscopic and bead dropping, found right hemisphere injured patients performed worse than left hemisphere cases on both tests, but the difference was only statistically significant for the haploscopic method.

After comparing left and right cases of parietal constructional apraxia on a perceptual test (Raven's Progressive Matrices), Piercy and Smyth (1962) wrote: "As a working hypothesis we adopt the formulation of bilateral but unequal representation and suggest that the right hemisphere may properly be regarded as dominant for these functions (i.e., visually mediated constructional skills - AM) in the majority of right handed people."

Considering the data, it also appears reasonable to apply this hypothesis to topographical orientation and depth perception.

Clinical Reports D: Figure recognition

Milner (1958) reports that patients with epileptogenic lesions of the right non-dominant temporal lobe have more difficulty interpreting sketches than do analagously lesioned left hemisphere cases. The right temporal group also take significantly longer to make their responses. Examining similar patients further, Kimura (1963) found that for tachistoscopic presentation of dots or overlapping nonsense figures the right temporal group performed significantly worse than the left temporal lesioned cases. Similar results were not observed for letters, overlapping familiar figures, or familiar objects. For recognition of recurring goemetric or nonsense figures (a visual memory task), the right parietal group were significantly more inaccurate.

In tests of recognition of incomplete or degraded figures, Warrington and James (1967) found no differences between left and right temporal lesioned patients; but the right parietal lesioned were significantly worse than the left parietal group. Similar results were obtained for visual retention tasks.

Clinical Reports E: Motion perception

Riddoch (1917) discusses ten cases in which wounds to the occipital region caused a loss of motion perception. He found that if there was recovery of motion perception, this would begin in the periphery of vision and progress

inwards. He also noted that in certain areas of the visual field in which motion could be detected, the identity of the object in motion could not. The areas in which motion could be detected were more central than the areas in which motion and shape could be specified. The visual field for motion was therefore larger than that for object recognition. In addition, in some cases, for a stationary object in the visual field, the presence of an object could be detected but not its shape. Lesion sites for these patients seem to have been evenly divided between left, right and bilateral.

Brain (1941) notes that patients with disorganized depth perception may also misjudge the speed of moving objects, especially in the sagittal plane (i.e., things moving towards or away from them).

In a study which included a test of apparent motion perception, Ettlinger (1956) found no difference in performance related to the laterality of the lesion.

Clinical disconnection of the cerebral hemispheres

Prior to surgery, the commissurotomy patients reported by Bogen and Gazzaniga (1965) could copy geometric figures better with their right hand. After section of the corpus callosum, both were superior with their left hand (operated by the disconnected right hemisphere). Even more marked post operative left hand superiority was observed in assembling Koh's blocks.

Using tachistoscopically presented chimeric stimuli, with split brained patients, Levy et al. (1972) found more

frequent choice of the left visual field stimulus for "antlers," familiar drawings and geometric column patterns, irrespective of the hand used to point out the match. For vocal naming, the right visual field stimulus was chosen more often. In further similar work, Levy and Trevarthen (1977) reported that the right hemisphere was dominant for the recognition of cursive writing, but when decoding was required, the left hemisphere took over.

Franco and Sperry (1977) required commissurrotomy patients to tactually choose a member of a particular geometric class (Euclidean, affine, projective or topological) to match the members of a visually observed set of objects. The left hand (right hemisphere) gave consistently high scores of around 80% correct for all the kinds of geometry. The right hand (left hemisphere) was always inferior, falling from about equal performance on Euclidean geometry in a gradation to chance levels on topological geometry.

When split brain patients were making decisions on the linearity, movement, shape or colour of stimuli in the peripheral visual field, Trevarthen and Sperry (1973) noted a strong involuntary right orientating bias. This, they say, "suggests that visual attention processes are more rightbrained for perception of large-scale peripheral stimuli lasting several seconds."

Hemispheric superiorities in monkeys

Concerning hemispheric lateralization of visual perception in monkeys, Gazzaniga's (1963) experiment

indicated that the memory for a cross/circle discrimination task was formed only in the right hemisphere. (An animal in these studies has its corpus callosum and optic chiasma surgically sectioned at the appropriate point in the experimental program.) On a problem requiring monkeys to discriminate between directions of motion, Hamilton and Lund (1970) reported a left hemisphere superiority. And Hamilton et al (1974) found a left hemisphere superiority for the discrimination of the orientation of lines on textured stimuli, but mirror image line patterns and monkey faces failed to show any lateral dominance over all animals.

However, it appears that these reports of cerebral dominance in monkeys should be viewed with caution since they have been criticized by Hamilton himself (1977). Bilateral memory traces were formed in a task similar to Gazzaniga's (1963), and for more difficult discriminations. Running additional animals in more carefully controlled studies (which for example balanced across subjects the hemisphere retracted during surgery), Hamilton has failed to corroborate his earlier reports.

Experimental studies with humans

In intact humans, cerebral dominance for visual nonverbal stimuli is examined using methods analagous to those discussed earlier for similar linguistic stimuli. In summary, stimuli are presented at suitable lateral displacements to the left and right of central fixation. Left visual field (LVF) stimuli go for initial processing

to the right hemisphere; those in the right visual field (RVF) initially go to the left hemisphere. A tachistoscope is typically used to present the brief stimuli required.

LaGrone (1942) required his subjects to report the number of dots presented bilaterally. Harcum (1978, p. 208) claims that LaGrone found more accurate reports for LVF dots. However, I am unable to extricate this result from LaGrone's idiosyncratic data tables.

Kimura (1966) reported LVF superiority for the enumeration of dots which on a particular trial were presented unilaterally. A similar LVF advantage was obtained for line forms but not for the enumeration of letters. For localization of single dots, Kimura (1969) found a LVF superiority for men but not for women when the subject was required to locate the dot in a defined square. When a circular location area was used, the result was a LVF advantage for both sexes. There were no field differences in the duration of dot exposure required for detection.

Filby and Gazzaniga (1969) obtained faster vocal reaction times to RVF dots. This might be expected given the left hemisphere's dominance for language output, but the magnitude of the difference, 30-40 ms, appears too large to be simply a callosal transmission time. In fact, McKeever et al. (1975) did not observe any significant

visual field differences when they attempted to replicate this experiment.

Davidoff (1977) found a right hemisphere superiority for the detection of dots of decreasing contrast for male subjects but no hemisphere effect for females. In a follow up experiment using males, low contrast LVF dots were correctly detected at shorter presentation times. The latter right hemisphere superiority was nullified by giving subjects a concommitant verbal recall task.

Subjects required to draw bilaterally presented dot figures drew those flashed up in the LVF more accurately. There was no such difference for solid line designs (McKeever & Huling, 1970).

Dallenbach (1923) using even more primitive stimuli (100 ms flashes of light) found that when stimuli correspondingly positioned in the left and right visual fields were judged equal, those presented in the LVF were physically less intense. The subjects were right handed. Dallenbach postulated a hemispheric explanation for his results, and predicted a RVF advantage for left handed subjects. He found this to be the case for some left handed observers (Burke and Dallenbach, 1924; White and Dallenbach, 1932).

Davidoff (1975) obtained similar results by presenting lateralized grey rectangles of various lightness to left and right handers. To right handers,

LVF stimuli appeared lighter. The converse was the case for left handers.

Concerning judgments of size, Stevens (1908a) wrote, "objects in the right half of the field of vision appear larger than exactly similar objects occupying symmetrical positions, in the left half of the field of vision." He favored a hemispheric explanation for his results and further reports, "seventy-six percent of the observers to whom the right disc looked larger to both eyes were right handed. Sixty percent of the observers to whom the left disc appeared larger were left handed." Though it should be cautioned that some of the experiments from which he drew these conclusions were fairly informal. However, with fewer observers but more careful measurement, Stevens and Ducasse (1912) obtained an overestimation of the length of the RVF stimulus relative to that of the LVF stimulus for right handed subjects. These results would argue, as Stevens and Ducesse do, against right hemisphere dominance for these observations.

Coren and Porek (1976) reported that of two equivalent white circular discs, the one viewed by the dominant eye appeared larger to the majority of subjects. Weinstein (1962) observed more impaired tactual size matching in right hemisphere lesioned patients relative to left hemisphere injured persons and normal controls. Nebes (1971), with commissurotomy patients, has found more accurate visual choice of circle size from an arc felt

with the left hand. Despite these reports, I have been unable to locate in the literature a modern hemispheric study of visual size matching with normal subjects. If no recent paper exists which supports or disputes Steven's finding, a well controlled replication would be in order since his RVF effect would not be predicted from current theory.

When weak luminous targets are viewed in the dark, they fragment and disappear. McKinney (1966) reported that with subjects fixating a central circle while viewing bilaterally presented targets, there is greater stability of the one in the RVF. The latency of this fragmentation is however 3 seconds or more, McKinney (1963), so whether this effect may be legitimately explained in hemispheric terms may be debated. McKinney (1967) in fact found this RVF stability to be related to eyedness rather than handedness. The effect was more pronounced in right eye dominant subjects, though he retained a hemispheric account for his results.

For right handed subjects, a light presented in the LVF must temporally precede an equivalent flash in the RVF for the two to be judged as simultaneous. Efron (1963a) accounted for his result as being due to the transmission time of the visual information from the right hemisphere across to the verbal left hemisphere where the decision "simultaneous" is made. More mixed results were obtained for left handers due apparently to some being right

brained for language. By increasing the intensity of the LVF stimulus relative to that of the RVF, for right handed subjects, the above effect could be reversed (Efron, 1963b). Thus, for the stimulus values used, inter-hemispheric transmission time may be decreased by increasing the intensity of the visual stimulus.

Jeeves and Dixon (1970) found that both left and right handed adults responded faster with their right hemisphere to lateralized 2 ms flashes of light. Jeeves (1972) confirmed this result for right handed children, but not for left handers. Bradshaw and Perriment (1970) also report faster right hemisphere response to point light sources.

In judging the depth of tachistoscopically presented rods, Durnford and Kimura (1971) found their subjects to be right hemisphere superior when the viewings were binocular. No laterality effects were observed for monocular viewings. Using Julesz stereograms in which the only depth cue available is binocular disparity, Durnford and Kimura (1971) again found the right hemisphere to be more accurate. The converse of the latter result has been reported by Richards (1970) using polarized lines. He states that his left hemisphere superiority "is largely due to the reduced chance of finding disparity detectors in the right hemisphere."

White (1971) found a RVF superiority for identification of line orientation. This result has been

criticized by Kimura and Durnford (1974) in that the few orientations of lines presented may have allowed verbal mediation (e.g., "horizontal," "vertical," "oblique"), and they report a LVF superiority for an eleven slope choice, as did Fontenot and Benton (1972) for a 10 choice paradigm. This contention is also supported by Berlucchi (1974) who reports a shift from RVF to LVF superiority when line orientation is made more difficult to code verbally. In a line orientation matching task in which "same"/"different" responses were required, Atkinson and Egeth (1973) observed faster LVF reaction times.

When using bilaterally presented nonsense or familiar line forms as experimental stimuli, Heron (1957) found no visual field differences. Similarly, Terrace (1959) with unilateral randomly occurring nonsense forms found no VF recognition differences for overall scores, but the majority of his subjects had better LVF scores.

Bryden (1960) presented bilateral rows of geometrical forms. He observed significant LVF recognition superiorities and that subjects tended to report left to right. When he required a reversed order of report, a RVF superiority was obtained. With unilateral presentation, he observed no differences. However, his bilateral stimuli extended across fixation, and the <u>outermost</u> edge of unilateral stimuli were laterally displaced only 1^{o} 8' from fixation. This does not ensure restriction of input to a selected hemisphere. He also used oral report.

Bryden and Rainey (1963), with more lateralized stimuli, found LVF superiorities for bilateral geometric forms and familiar objects, but a RVF advantage for unilateral familiar objects.

Repeatedly presenting line drawings until they were recognized, Wyke and Ettinger (1961) obtained a RVF superiority.

Kimura (1966) found no VF differences in the recognition of unilaterally presented nonsense figure pairs. In a subsequent experiment where a "same"/"different" response eliminated memory mediation, again no VF differences were observed, Kimura and Durnford (1974). These authors have also been unable to replicate the results of Bryden and Rainey (1963), and Wyke and Ettlinger (1961), with standard, mirrored or inverted versions of familiar line drawings.

For matching pairs of black geometric shapes (a "same"/ "different" decision), Beaumont and Dimond (1975) found superior reaction time and percent correct rates for stimuli presented to the right hemisphere. White and White (1975), matching 2-4 black geometric shapes, also reported better right hemisphere performance. But Umilta et al (1978), using pairs of outline figures (again a "same"/"different" response) observed a left hemisphere superiority for simpler shape and nonsense figure matches, and a right hemisphere advantage only for the most complex geometrical figures used.

Hines (1975) observed a RVF superiority for shape recognition irrespective of whether subjects viewed the stimuli bilaterally paired with another shape or a word. Earlier, Hines (1972) had also reported a RVF advantage for bilaterally presented shapes, but later Hines (1978) found no significant field differences for shapes.

Goldberg et al (1978) using textured shapes, found that the left hemisphere processed shape better than the right hemisphere, while for processing texture, the left was poorer.

Thus, although on the basis of lesion studies (especially cases of visual object agnosia) and split brain tachistoscope experiments, one would expect the right hemisphere to predominate in the perception of shape, this is not consistently observed empirically with normal subjects.

In visual masking, the perception of a target stimulus (TS) is degraded or eliminated by a masking stimulus (MS) which optically occupies the same or an adjacent region of visual space. In backward visual masking, the MS temporally follows or is concurrent with the TS. The time interval between the offset of the TS and the onset of the MS is termed the inter stimulus interval (ISI). The critical ISI is the minimum ISI which no longer interferes with the TS. The stimulus onset asynchrony (SOA) is the time from onset of the TS to onset of the MS.

Oscar-Berman et al. (1973) report that for normal subjects the critical ISI is shorter for words and nonsense shapes presented in the RVF. Conversely, Oscar-Berman et al. (1976) found shorter LVF critical ISI's and SOA's for musical notes but no such differences for letters. However, McKeever and Suberi (1974) showed that the LVF SOA function for letters lagged the RVF function by around 13 ms. And Cohen (1976), also with letter stimuli, writes, "masking produced a significant decrement in the LVF, but not in the RVF."

In these experiments, the critical ISI or SOA is interpreted as being a measure of processing or encoding time. Shorter values indicate faster processing or encoding. The results favour the left hemisphere.

It should also be briefly noted that visual masking effects are frequently observed in experiments on apparent motion (and apparent movement in visual masking studies), (Wertheimer, 1912; Korte, 1915; Kahneman, 1967; Weisstein and Growney, 1969; Mackenzie, 1971), though the precise nature of the relationship between the two phenomena remains contentious.

Stevens (1908b) reports that objects in motion in the RVF appear to move faster than those moving at equal rates in the LVF. This he accounts for in terms of his earlier finding (Stevens, 1908a), that lengths, etc. appear greater in the RVF. Gengerelli (1948) with an experimental setup in which either interhemispheric or

intrahemispheric apparent motion might be observed, found that the intra hemispheric case was most often reported.

When two visual targets are positioned in the midline of vision but at different distances from the subject and one target is fixated foveally, the other target may be seen diplopically at equal distances to the left and right of the fixated target. If the targets are flashed on and off alternately so as to produce apparent motion, the fixated target may be perceived as splitting and moving in both directions towards the two images of the other target; or motion towards one of the images may predominate with suppression of the other direction of motion. According to Carter (1953), subjects usually initially report splitting motion, but after about 30 secs observation, a single direction maintains. Depending on whether the near or far target is fixated, the direction of movement which predominates may be interpreted as indicating which cerebral hemisphere (or eye) is dominating the perception of motion. Jasper (1932) and Jasper and Raney (1937) report that the majority of right handed subjects were left cerebral dominant for this task, whereas left handers tended to be right dominant. Ambidextrous subjects were evenly divided.

Jasper's experiments have been criticized by Carter (1953) in that no fixation spots were provided. Carter modified his apparatus appropriately, and additionally

introduced a "three target situation," in which two targets were placed one on either side of the distant target, while the near target of the Jasper setup was removed. This modification also allows monocular viewings. Carter's results for both the two and three target situations were in good agreement. He found right handers tended to be left hemisphere dominant, while left handers appeared to be more mixed. Note, however, that in these experiments stimulus viewings are over a period of minutes.

In a discriminative reaction time task, Bertoloni et al. (1978) found that the right hemisphere was faster in detecting rates of motion.

Concluding comment

Overall, the glib statement that, "for normal right handed subjects the right hemisphere is superior for visuo-spatial tasks," cannot be accepted without reservations. Though it should be recognized that many of the pertinent experiments can be criticized on methodological grounds.

The experiments to be reported in this thesis examine cerebral hemispheric differences in real motion; apparent motion under various stimulus conditions; apparent motion in depth; and shapes in apparent motion.

First, however, the methodological precautions which must be considered when conducting hemisphere experiments will be discussed.

Chapter 2

Hemispheric Experimental Methodology

In this chapter, the experimental problems particular to hemispheric research are examined. The techniques which were used to control for and hopefully eliminate potential spurious results are presented.

As can be seen from the schematic figure 2.1 when a human observer foveally views the fixation spot (F), stimuli presented in the left visual field (LVF) are transmitted directly only to the right hemisphere; and stimuli in the right visual field (RVF) to the left hemisphere.

Information from the central region of the visual field, B, is received by both hemispheres. This area of bilateral representation extends to around 2.5^{o} visual angle (VA) on each side of fixation (White, 1972).

Thus, to ensure that visual stimuli are being presented to only one cerebral hemisphere, lateral stimulus displacements should be 2.5^{o} VA or greater with the subject fixating centrally. In the experiments to be reported, the least lateralized point of all stimuli (i.e., the point on the stimulus nearest to fixation) satisfied this criterion. The actual displacements used in each experiment are detailed in the method section of each study.

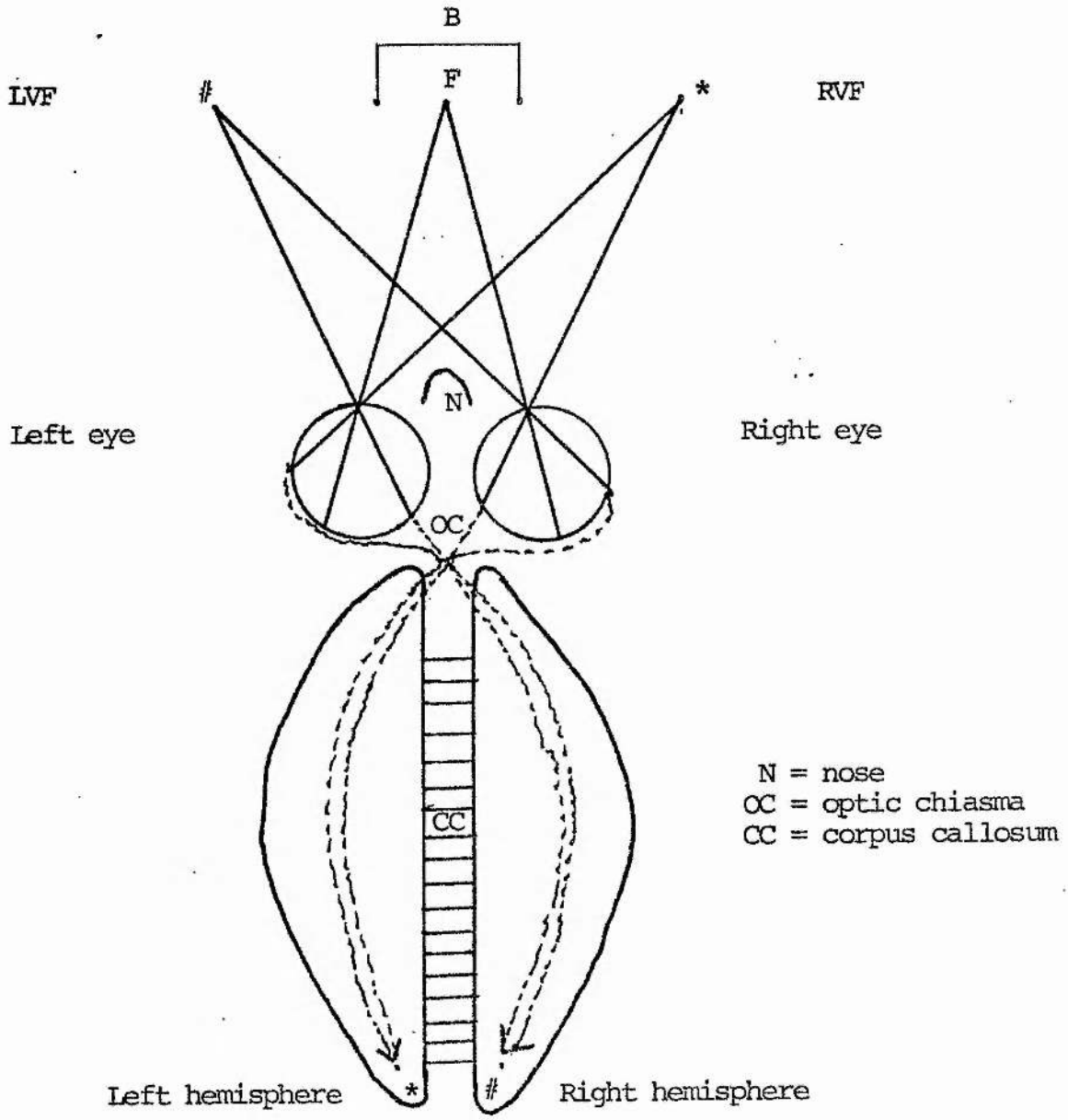


Figure 2.1

Schematic diagram of the human visual system. Visual field stimuli are received by the contralateral cerebral hemisphere.

A number of techniques have been employed to check that the subject is actually fixating the central spot. Mishkin and Forgays (1952) directly observed their subject's eyes, "if eye movement occurred at the moment of exposure the response was discarded." LaGrone (1942) watched whether his subjects' eyes deviated from fixation by using a mirror. Gazzaniga et al. (1965) observed their patients' eyes through a hole at fixation and "presented stimuli only when the subject's gaze was firmly centered." Maddess et al. (1973) used a viewing technique similar to the latter, but with a "telescope" at fixation. They compared this monitoring method with side viewing and found the "telescope technique" to be superior. Trevarthen and Tursky (1969) recorded their subjects' head movements by means of a counterweight apparatus, and eye movements by electrooculograph. Closed circuit TV was used by Bertoloni et al. (1978). Two further methods are noted by Dimond and Beaumont (1974). Since the iris and sclera reflect different amounts of light, eye movements may be detected by monitoring changes in reflected light. Alternatively, with polarized light, the subject is required to maintain Haidinger's Brush in alignment with the fixation point.

Other such "fixation forcing" techniques have been applied; for example, Ayres (1966) presented a brief duration light at fixation. Only when this light was on could the subject expose the target. Sperry (1968)

required his subjects to report a small letter or number briefly presented at fixation. This procedure has also been used by McKeever and Huling (1971a, b). The latter technique has been criticized by Hines (1972) in that it may instigate a rightwards reading scan from fixation, or interfere with stimulus recall. However, McKeever et al. (1972) have contested these points.

Kinsbourne (1970) has shown that in a visual detection experiment in which no laterality affects were obtained, the introduction of concommitant verbal recall gave rise to a RVF superiority in detection. Kinsbourne attributed this change to an activation of the left hemisphere by the verbal task. Whether requiring a subject to report a letter or digit at fixation activates the left hemisphere is uncertain. This suggestion has largely been rejected by Hines (1978). However, it appears safest not to use this type of fixation forcer when conducting purely visuo-spatial experiments.

In the absence of sophisticated eye monitoring equipment, one may be reassured by the empirical evidence that subjects are able to maintain fixation during the brief stimulus durations required. Riggs et al. (1954) have examined eye movement records for fixation on a black dot in a bright field. Their data indicate that during 0.1 sec "the retinal image typically moves through a distance corresponding to 25 sec of arc, approximately the diameter of a single retinal cone. Thus we may say that

0.1 sec is often a practical exposure time for the control of eye movements."

It has also been shown that subjects are responsive to fixation directions. Bryden and Rainey (1963) observed enhanced laterality effects for "strong" fixation instructions.

A warning tone which heralds a stimulus presentation assists subjects in maintaining fixation at the correct times.

To ensure hemispheric lateralization, VF lateralization is required. In non-random unilateral stimulus presentations, the subject views blocks of trials in one VF at a time. This paradigm may introduce a shift in fixation towards the field of the stimuli, or a shift in attention towards that field, since the subject knows, or quickly learns, where stimuli will appear. With bilateral stimulus presentations, stimuli always occur in both visual fields. Though the likelihood of shifts in attention are less than in the unilateral case, the subject may choose to concentrate selectively on one field, knowing that he will be almost always sure of correctly identifying at least one of the two stimuli. It is also possible that repeated bilateral presentations may trigger a well practiced left to right reading scan. For these reasons, random unilateral presentations are preferred. In this design stimuli are presented unilaterally on any particular trial, but within a block

of trials the side on which a stimulus will appear is randomized. Since stimuli appear in both visual fields during an observation period, the subject's fixation is not selectively drawn to one side. For any particular presentation, he cannot know in advance on which side the stimulus will occur. Also, if he concentrates on one visual field, he is almost certain to miss all stimuli presented in the other.

Even with random unilateral presentations and the subject initially fixating the spot, if the stimulus duration is too great the subject can shift his gaze to look directly at it. If the stimulus is brief enough, i.e., within the latency of eye movements, this artefact may be avoided.

Westheimer (1954) found that the latency of eye movements varies between 120 ms and 180 ms. The minimum latency mentioned by Corvitz and Laves (1962) is 150 ms. While Saslow (1967) reports latencies of around 200 ms irrespective of whether two, four or eight possible new target positions were used. Robinson (1965) who examined eye tracking of a stimulus which starts to move, states, "the time required for the eye to accelerate from rest to any velocity from 5 to 20 deg/sec is about 130 ms." Of course in these experiments subjects were instructed to shift fixation to the new stimulus position.

Potential errors of fixation and attention were controlled in the experiments to be reported in the

following manner: Subjects were shown the central fixation spot and told that they should be fixating this during stimulus presentations in order that meaningful data might be obtained in the experiment. At all relevant times, e.g., after a break when they were about to recommence observations, they were reminded of the importance of fixating the dot. They were told that they would receive a warning tone through headphones which would inform them when to fixate. Presentations would be unilateral but random so to maximize their chance of perceiving the stimulus they should be centrally fixated.

In all experiments stimulus presentation durations were well within the latency of eye movements and less than or equal to the 0.1 sec which Riggs et al. (1954) have recommended. The instuctions to subjects and the actual stimulus durations used are specified in detail in the method sections of the individual experiments.

In experiments in which VF differences are frequently interpreted in terms of cerebral hemispheric superiorities, it is surprising that few writers have been concerned about whether stimuli of equal detectability are being presented in each visual field. Experimenters seem to assume without checking that their equipment is "balanced." Only White (1972) has suggested that "it is possible to explain the results from two of Kimura's experiments (1969) in terms of relative stimulus

refraction and the properties of planar tachistoscope mirrors."

The equipment used in the studies to be reported was checked for VF disparities by conducting mini experiments. The most sensitive equipment available for VF checks was the human visual system. In one set of checks, observers foveally fixated the VF in which the stimulus was to appear and trials were run to threshold. In this situation, there are no hemispheric effects in play and VF differences would indicate equipment imbalance. Another test involved positioning temporary fixation spots on the far side of each stimulus field. With fixation on these, each VF could be checked with each cerebral hemisphere. These techniques are described in detail in the method sections of the experiments. In no case did these tests reveal VF differences in the equipment.

The literature reviewed in Chapter One has shown that the right hemisphere is typically inferior with respect to language function, and especially so with regard to spoken output. Requiring a subject to give a verbal response places the right hemisphere at a disadvantage. There is a strong likelihood that decisions made by the right hemisphere would have to be transferred across the corpus callosum to the left hemisphere for verbal expression. Also, verbal mediation may activate the left hemisphere in a manner similar to that discussed earlier concerning letters at fixation.

In the experiments to be reported, a manual response was used. However, since contralateral motor pathways predominate, requiring unimanual responses would favor, and possibly even activate the processing capacities of the cerebral hemisphere controlling the responding hand. Subjects were therefore required to complete a balanced half of an experiment with each hand.

Poffenberger (1912) showed that reaction times were faster when the response required was on the same side as the stimulus. Filbey and Gazzaniga (1969) found that when subjects were asked to move a lever to the left or right in response to a dot or no dot, there was "considerable response competition." A lateralized dot tended to trigger a response towards it irrespective of the experimental instructions. Craft and Simon (1970) in a choice reaction time task, observed slower RTs when the lateral position of the stimulus conflicted with the side of the response button. They postulated, as did Simon (1969), a "basic natural tendency to respond towards the source of stimulation." Craft and Simon (1970) also noted more errors in the conflicting S-R situation.

To control for S-R compatability in their hemispheric study, Bradshaw and Perriment (1970) developed a technique in which subjects responded with their first and second fingers and "the operating hand held either in pronation or in supination."

However, it appears that S-R compatability may be controlled for in laterality experiments simply by positioning a single two-way switch centrally in front of the subject and requiring him to move it either towards or away from him. This setup was employed in the experiments to be reported. In some experiments the response was highly compatible with the stimuli since the subject had to move the switch in the same direction as the motion presented. These directions were up or down. If the motion appeared to be upwards, the subject was to move the switch up, i.e., away from him; and conversely down (towards him) for downwards motion. It was stressed that this was to be the response irrespective of the VF in which motion occurred.

As was discussed in Chapter one, ambidextrous and lefthanded people tend to be much more mixed with respect to cerebral dominance than right handers. For this reason, in the hope of obtaining more clearcut results, only right handed subjects were used.

A range of performance tests, e.g., handwriting, dart throwing, dexterity, hand-grip strength, etc., Provens and Cunliffe (1972), or a peg board task, Annett (1972), have been used to measure handedness. For the same purpose, a number of questionnaires have been developed (Crovitz and Zener, 1962; Oldfield, 1969; Provens et al, 1974).

The questionnaire used in the current studies was a modified version of the 75 item one examined by Provens et

al. (1974). It consists of 16 laterality items and is presented in Appendix A. The handedness score obtained by each subject was computed simply by algebraically summing the scores on items 1-16 and dividing by 16.

Basser's (1962) clinical studies have shown that language typically develops bilaterally in children, with lateralization to one hemisphere occurring later. Lenneberg (1963) states, "no lateralization seems to be present before age two or three; then there is a period that lasts to about age ten or twelve during which cerebral lateralization for speech is gradually established but may still be pushed back into the right hemisphere if the left hemisphere is disturbed. After puberty, lateralization is normally firmly established to the left, and the right hemisphere is no further involved in speech functions." Split brain studies suggest that the initially acquired basics of language are retained by the right hemisphere, while more complex grammatical structures are mediated by the left.

Kimura (1963) using a dichotic listening task found right ear superiorities in children as young as age four. Such results have been replicated by Kimura (1967), Knox and Kimura (1970), Bever (1971), and Bryden (1970). The age of the subjects ranged from 2.5 to 12 years.

In a tactile-visual shape identifying task, Witelson (1975) found significantly superior left hand performance

for boys aged 5 years and upwards; girls failed to show this effect until about 13 years.

Although there appears to be a considerable age range over which cerebral differrentiation develops in children, clinical and experimental studies indicate that the process is fairly well completed by post-adolescence. In the experiments to be reported, most groups of subjects were undergraduates aged around 20 years. In one experiment the subjects were high school pupils, mean age 16.5 years. Therefore, all subjects would be expected to have completed their development of lateralization.

In a comprehensive review, Harris (1978) has shown that males outscore females on numerous visuo-spatial tasks. The differences are often observable in children as well as adults. Boys appear to understand many visuo-spatial concepts at earlier ages than girls. Tasks in which male superiority has been observed include embedded figures, visual imagery of letters, mental rotation of figures, three dimensional block enumerations from two dimensional drawings, geometry, chess, Porteus maze test, tactual mazes, pattern walking, map reading, left-right discrimination, aiming and throwing, pursuit motor, target tracking, rod and frame test, geographical knowledge, and some Piagetian tests.

Conversely, girls tend to speak earlier than boys, accumulate vocabulary faster and are first to use more complex grammatical structures.

The series of experiments to follow are primarily visuo-spatial. In all studies subjects of both sexes were used. In addition, the majority of subjects were probably of above average intelligence and all reported themselves free of neurological injury or abnormality.

The rationale for adopting particular experimental procedures has been presented. It is hoped that by using these techniques, artefactual results have been eliminated and that laterality differences, when they are observed, accurately reflect differences in the processing capacities of the cerebral hemispheres and are not a function of faulty experimentation.

In the following chapters, the experiments which were conducted to examine hemispheric differences in motion perception are reported.

Chapter 3

Experiment 1 - Hemispheric differences in the perception of real motion

Introduction

The human visual system is highly sensitive to motion; for example, a completely camouflaged bird or animal becomes immediately visible when it begins to move.

Lower species than man have also evolved excellent motion perception. Gibson (1958, 1961, 1966) has discussed how important vision is to animals as they move around in the environment, and the "transformations of the optic array" which occur when the animal avoids stationary obstacles or moving projectiles, pursues prey or flees from danger. He consideres these optical transformations to be stimuli for the eye. An animal which is capable of correctly interpreting such optical information may respond appropriately to events within its visual range.

Physiological studies have shown that within the frog's visual system, there are cells which are sensitive to the type of motion which would be produced by prey, and other cells responsive to the movement of larger objects analogous to that of predators (Lettvin *et al*, 1959; Maturana *et al*, 1960).

In mammals, directionally selective units have been discovered. "The term 'directionally selective' means

that a unit gives a vigorous discharge of impulses when a stimulus object is moved through its receptive field in one direction (called the preferred direction), whereas motion in the reverse direction (called null) evokes little or no response" (Barlow and Levick, 1965). Such cells have been examined in the rabbit's retina (Barlow and Hill, 1963; Barlow, Hill, and Levick, 1964; and Barlow and Levick, 1965).

However, motion detecting cells have not been observed in the more peripheral regions of the cat's visual system. To quote Hubel and Wiesel (1962): "In the cat's retina, one can distinguish two types of ganglion cells, those with 'on'-centre receptive fields and those with 'off'-centre fields (Kuffler, 1953). The lateral geniculate body also has cells of these two types; so far no others have been found (Hubel and Wiesel, 1961). In contrast, the visual cortex contains a large number of functionally different cell types."

Hubel and Wiesel have studied cells in the cat's striate cortex. They found directionally selective units, and other cells which responded to movement in both (opposite) directions. The units studied were particularly sensitive to the orientation of a moving slit of stimulus light and to variations in the rate of its motion (Hubel, 1959; Hubel and Wiesel, 1959).

The same investigators have replicated and extended these results (for example, with regard to the color and

size of the stimuli to which cells selectively respond) in the monkey (Hubel and Wiesel, 1960, 1968).

The presence of directionally selective units in the human visual system is indicated by more indirect means.

In the waterfall illusion, the observer stares for a few seconds at a stimulus which is continuously moving in a particular direction. When his gaze is shifted to stationary objects, they appear to move in the opposite direction. Similarly a rotating spiral which appears to expand is seen as contracting when its motion is stopped.

Continuous viewing of such stimuli and the effects thus produced are termed selective adaptation. Such effects have been used to study directionally selective mechanisms in the human visual system.

Sekuler and Ganz (1963) required their subjects to view a vertical grating moving, e.g., from left to right. After this adaptation period, the observer then views low contrast test gratings moving in the same, or reverse, direction. It was found that for the two test cases, contrast thresholds were higher for gratings moving in the direction of the adaptation pattern. These results indicate the presence of units adapted by (and therefore specifically sensitive to?) a particular direction of motion.

Gratings of the same spatial frequency and contrast moving at the same speed in <u>opposite</u> directions when optically superimposed produce a counterphase grating

which appears to pulsate with the dark bars becoming light and conversely. Threshold contrast studies using counter-phase gratings (Levinson & Sekuler, 1975; Sekuler & Levinson, 1977) indicate that there are units in the human visual system that independently detect the two opposite directions of motion.

More general evidence of such units has been produced by Levinson and Sekuler (1976). When an adapting field of flowing random dots is viewed prior to a test field of dots moving in another direction, the apparent direction of the test dots is rotated away from the adaptation motion vector. "This direction shift is easily understood if one assumes that the neural code for perceived direction depends on a set of direction-specific mechanisms, each tuned to a somewhat different direction" (Sekuler & Levinson, 1977).

Thus the psychophysical evidence from human subjects appears to parallel that obtained physiologically from higher mammals. This leads us to conclude that there are systems in the human visual cortex which selectively respond to specific directions of motion. And that, as in the cat and monkey, such units do not occur at levels in the visual system prior to the cortex.

The clinical studies reviewed in Chapter One also suggest a cortical location for motion perception (Riddoch, 1917; Brain, 1941).

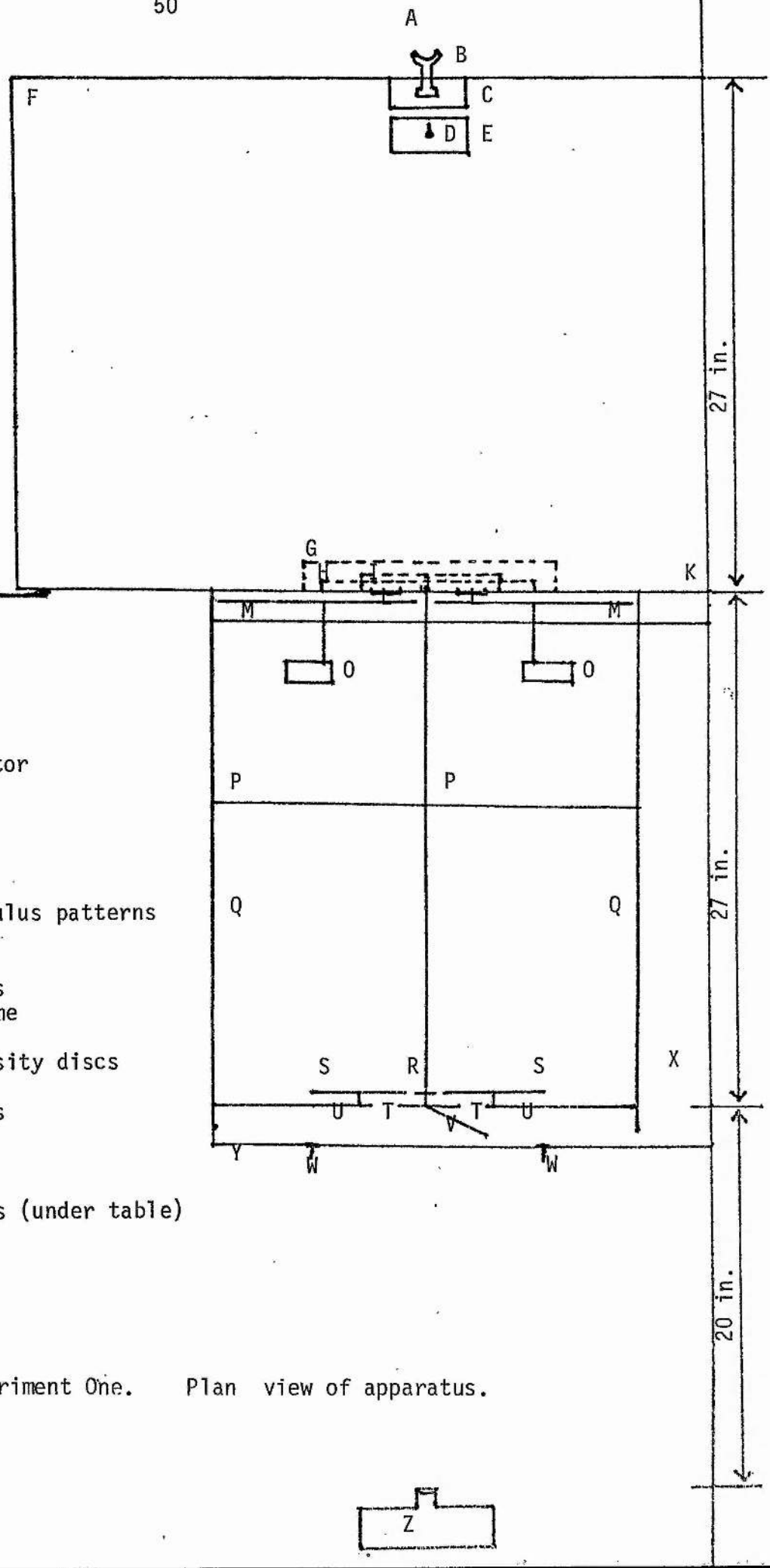
With normal subjects, cerebral dominance effects have been reported for very basic visual stimuli. This literature is also reviewed in Chapter One, but to recap briefly on some examples: detection of low contrast dots (Davidoff, 1977); lightness judgments (Dallenbach, 1923; Davidoff, 1975); fragmentation of luminous targets (McKinney, 1966); response to flashes of light (Jeeves & Dixon, 1970; Bradshaw & Perriment, 1970); depth perception (Dunford & Kimura, 1971; Richards, 1970); line orientation (Kimura & Dunford, 1974; Berlucchi, 1974; Fontenot & Benton, 1972); visual masking (Oscar-Berman et al, 1973; McKeever & Suberi, 1974; Cohen, 1976); and predominant direction of apparent motion (Carter, 1953).

Given such findings, a series of experiments was conducted to examine hemispheric differences in motion perception.

The first experiment was concerned with real movement, with stimuli presented to either the left or right hemisphere. Subjects were required to correctly report the direction in which the stimuli moved.

Apparatus and Procedure

The experiment was conducted in a windowless 6 ft 8 in high, 9 ft 3 in long, wedge shaped experimental cubicle; 6 ft 2 in wide at the experimenter's end and 3 ft wide where the subject sat. The cubicle was divided into



A = seated subject
B = adjustable bite bar
C = bite bar stand
D = 2 way switch
E = switch mounting
F = 36 in. x 27 in. table
G = aluminium shade/reflector
H = filament lamp
I = opal perspex diffuser
J = fixation light
K = hardboard partition
L = viewing windows
M = perspex discs and stimulus patterns
N = blackout curtain
O = electric motors
P = tracing paper diffusers
Q = light constraining frame
R = pointer
S = calibrated neutral density discs
T = light vents
U = potentiometer mountings
V = pivoted flap
W = motor switches
X = 30 in. x 27 in. table
Y = electronic timing units (under table)
Z = projector

Scale 1 in. = 8 in.

FIGURE 3.1 : Experiment One. Plan view of apparatus.

two parts by a hardboard partition and blackout curtain 4 ft 3 in from the narrow end. The subject sat in this area, while the experimenter worked in the remainder of the room. A plan of the room and equipment is shown in Figure 3.1.

A shaded angle-poise lamp, with an additional tracing paper diffusing cover, illuminated the experimenter's working area. A light constraining frame, which was constructed of wood and painted matte black, channelled the light from a gaf 600 auto tachistoscopic projector to one or other of the two viewing windows. The frame was 27 in long, 5 in deep, and a wooden partition about which the light frame was symmetrical, divided it into two 11 in wide sections. This partition prevented light intended for one viewing window from reaching the other. The frame was made as light-tight as possible and any potential points of light leakage (e.g., where the frame met the table) were sealed with opaque insulating tape. The frame was positioned with the central partition exactly between the two viewing windows and bracketed firmly to a table which was in turn fixed rigidly to the wall.

During the experiment, a hardboard cover excluded extraneous light from the frame. A slide, opaque except for a transparent central rectangle, was placed in the projector to produce a similar area of even illumination extending over both circular light vents. These light

vents, one on each side of the central partition, were 1-1/2 in in diameter, separated at their nearest points by 1 in, and positioned 3 in above the table on a level with the viewing windows. They were covered with tracing paper to diffuse the light from the projector.

An opaque flap, which could be flicked from side to side to cover one light vent and allow light to pass through the other, was mounted on the light constraining frame.

Two potentiometers were fitted to the light constraining frame, one on each side of the light vents. The shafts of the potentiometers passed through the frame and on each of these shafts a graduated 1-1/2 log unit neutral density disc was mounted. These identical discs were 4-1/2 in in diameter, and the circumference was calibrated using a strip of graph paper. The total circumference was 29.4 units. Light which came through the light vents from the projector could be attenuated accurately as it passed through the neutral density filters and readings from these discs were used as a measure of contrast during the experiment. Numerically higher readings from the neutral density discs represent lower contrast levels at the viewing windows, i.e., higher readings indicate greater sensitivity on the part of the observer (hemisphere).

A sheet of tracing paper, stretched across the frame 16 in from the light vents, further diffused the beam from the projector and eliminated any remaining focused light.

Moving shadows cast on the viewing windows by rotating radial random patterns, see Appendix B, Figure 1 (Anstis & Rogers, 1975), formed stimuli for the experiment. Each item of texture of these patterns had an equal chance of being either opaque or transparent. The radial size of the texture items increased with increasing distance from the centre, so that, although any point on the circle rotates faster as its distance from the centre increases, the number of texture items passing any fixed point is constant.

The patterns were printed on photographic negative paper so the black areas of Appendix B, Figure 1 were transparent. They were mounted on 10 in diameter, 0.125 in. thick, clear perspex discs which were rotated during the experiment by Raleigh Instruments electric motors. In this experiment, the motors were set to rotate at 6 rpm, and could be independently switched on to rotate either clockwise or anticlockwise by switches at the experimenter's end of the table.

When illuminated by a flash of light from the projector, the rotating disc cast a shadow on the appropriate tracing paper viewing window. The tracing paper was kept rigid by clear perspex and the contrast of the cast shadow reduced by gelatin neutral density filter over the perspex (Figure 3.2).

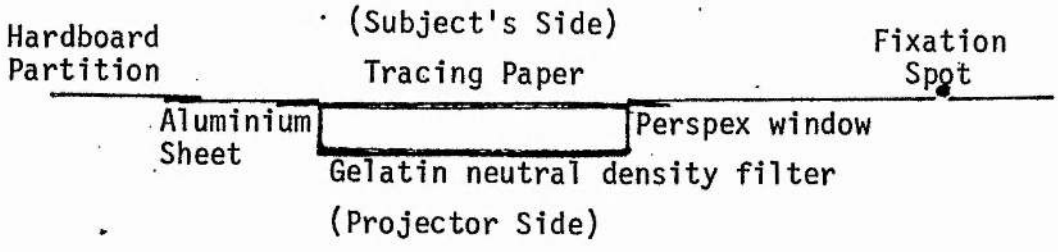


Figure 3.2 Plan of a Viewing Window

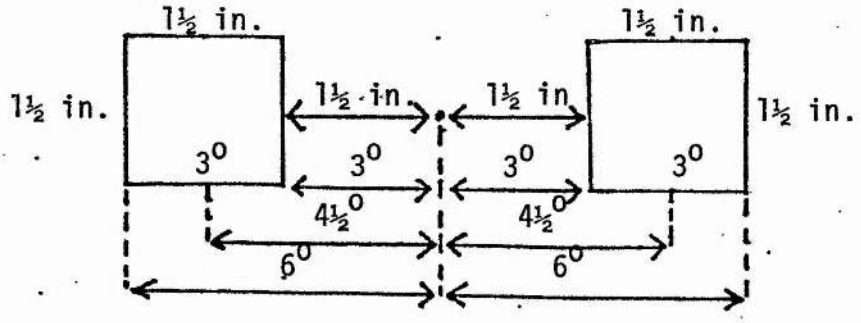


Figure 3.3 Dimensions of the Viewing Windows

Scale 1 in. = 2 in.

The viewing windows were 1-1/2 in square and their nearest edges 1-1/2 in from fixation. The subject was seated with his eyes 27-1/2 in from the window, and at this distance 1/2 in $\triangleq 1^{o}$ visual angle (VA). Thus the innermost edge of a window subtended a VA at the subject's eye of 3^{o}, the outermost edge 6^{o}, the midpoint $4\text{-}1/2^{o}$, and the windows themselves were 3^{o} by 3^{o} VA (Figure 3.3). From the discussion in the previous chapter, therefore, when the subject is fixating steadily on the fixation spot, and a stimulus is displayed in one window, this stimulus information flashes to the contralateral hemisphere and is not directly available to the ipsilateral hemisphere.

The stimulus discs were mounted with their centres level with the mid points of the viewing windows. The distance from the centre of a disc to the nearest edge of its window was 3-1/4 in. Thus, when the disc rotated past the window under strong illumination, the impression of motion to an observer was predominantly upwards or downwards, depending on the rotational direction of the disc. Accordingly, subjects in the experiment were asked to respond to their perceptions of stimulus motion in those terms (i.e., motion "up" or "down").

The distance from the center of a disc to the centre of its window was 4 in. With the disc rotating at 6 RPM, the mean distance traversed by a point of texture during

the 100 ms stimulus exposure = 0.25 in, which from the subject's viewing position = 0.5^{o}VA.

The fixation spot was a 6 V 40 ma red filament bulb, and was switched on 1 sec prior to each stimulus presentation.

The eye level viewing windows were illuminated on the subject's side by two 11 in 60 W 240 V filament strip lights each positioned 8-1/4 in directly above and below the windows, Figure 3.4. Two aluminium shade/reflectors which were sloped slightly outwards, directed the light evenly onto the windows and away from direct entry into the subject's eyes. Two opal perspex shades, mounted horizontally above and below the windows, diffused the light falling on the windows and prevented high spots of illumination.

Subjects sat behind a fixed table on which a vertically adjustable bite bar stand was rigidly mounted. An aluminium bite bar covered in dental wax was adjusted to a height such that the seated subject could comfortably look at the fixation spot. The bar was then dipped in hot water to soften the wax, rigidly screwed to the stand, and an impression made with the subject looking directly at the fixation spot. During the experiment, when the subject bit the bar, his teeth fitted into the impression and his head was thus held rigidly in the correct position.

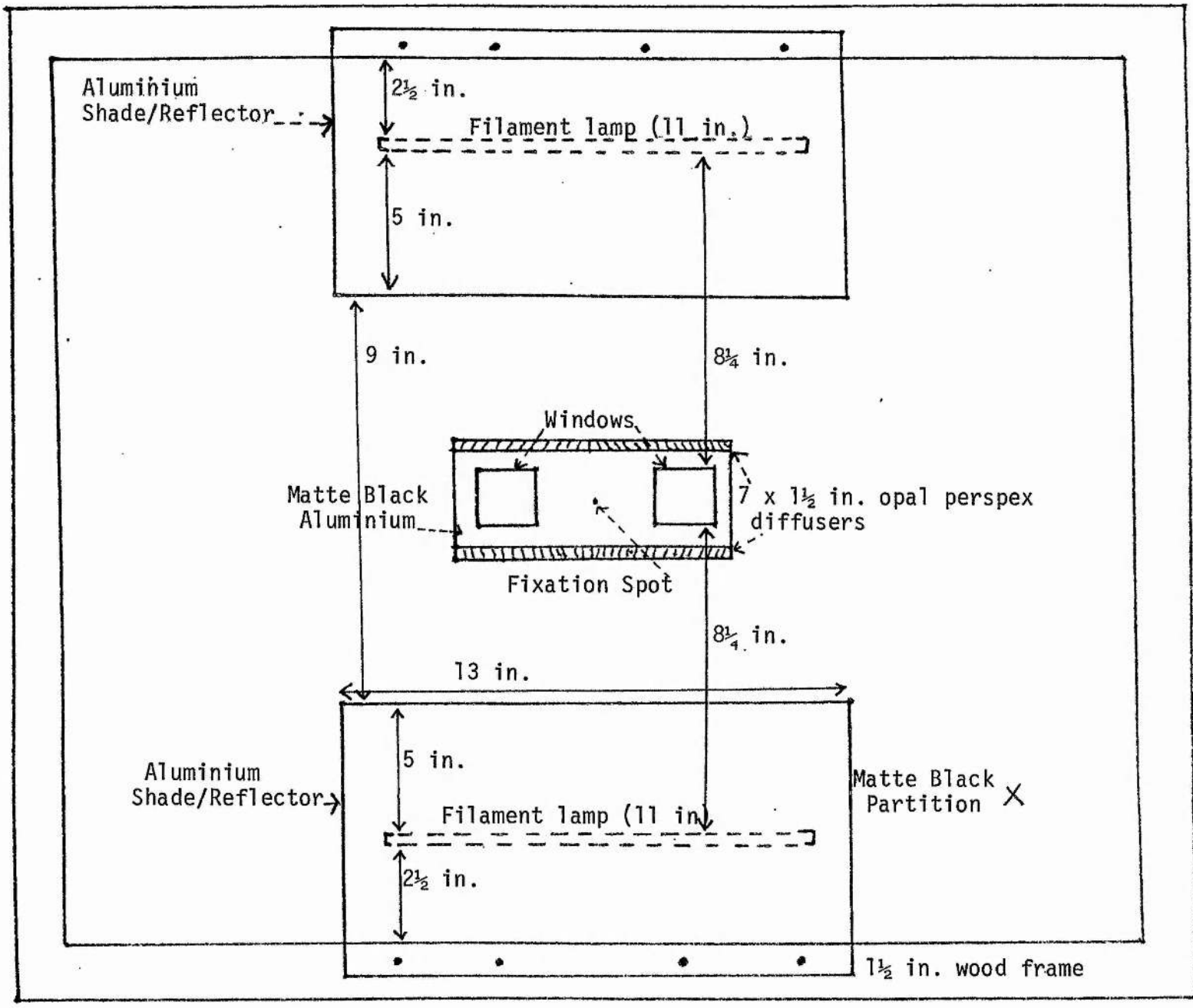


Figure 3.4

EXPERIMENT ONE. Apparatus from the subject's viewpoint.

A self centring two-way switch, which could be moved either backwards or forwards, was mounted on a rigid aluminium frame upon which the subject could rest his responding hand, and positioned centrally in front of him. The switch protruded vertically from its mounting and was held by the subject between the thumb and first finger of his responding hand. The subject was requested to respond to upwards motion by moving the switch up (i.e., forewards, away from him), and to downwards motion by moving the switch down (i.e., back towards him) irrespective of which side the motion occurred. The switch was connected to an electronic digital display from which the experimenter could read off and record the subject's response.

Electronic timing units also controlled the sequence and duration of the fixation spot and the flash from the tachistoscopic projector. The duration of the flash was 100 ms which is well within the latency of eye movements.

During the experiment, the subject was required to wear stereo headphones over which white noise was played at the same intensity in each ear. This concealed the sound of the motors and masked any other extraneous noises. Dipping the intensity of the white noise by the experimenter was a signal to the subject that a trial was about to take place, and he should bite the bar firmly and focus on the fixation spot. All stimulus viewings during the experiment were binocular.

Pilot Studies

During construction of the original apparatus, the experimenter in conjunction with a number of assistants monitored the apparatus for defects which might have resulted in the production of unsatisfactory data, e.g., the contrast levels of the cast shadows were too high prior to placing neutral density filters over the perspix viewing windows.

Prior to running subjects in the experiment, pilot studies were conducted to test the apparatus and check the stimulus parameters. It was found that the pre selected 100 ms flash duration was satisfactory, and the scale units on the neutral density discs reduced the contrast by suitable steps.

Assistants could respond to around 40 stimulus presentations before requiring a break.

This experiment therefore proceeded much as originally conceptualized.

(However, an attempt to use the same apparatus to conduct an analogous study of apparent motion, with a stroboscope replacing the projector, was doomed owing to deficiencies in the stroboscope.)

Window checks

Prior to any data collection, to ensure that any "hemispheric" effects which the experiment revealed, could justifiably be attributed to laterality differences in the subject and not to any differences inherent in the

stimulus display, a number of pre-experiment checks were carried out. The viewing windows were examined empirically to ensure that equal stimulus information would be available to the two hemispheres during the experiment proper. The most sensitive available method of checking the equality of the stimuli was to use a human observer. The experimenter was assisted in these checks, carried out before the experiment proper began, after running a number of subjects and again at completion, by eight people, some of whom participated in all checks, and who became highly sensitive to slight differences in the visibility of the stimuli. One check involved the assistant fixating foveally on one of the two windows while the experimenter ran a series of trials to threshold using the staircase method employed in the experiment proper. Then the assistant's threshold for direct observation of the other window was similarly found. Alternatively, the assistant would be instructed by the experimenter to look directly at whichever of the two windows the stimulus was about to appear in, as randomly determined by the data sheet. Again, the subject's threshold for direct observation of each of the two windows was found as in the experiment proper. It is clear that in these cases, with the window fixated foveally each time, there is no possibility of hemispheric effects, and if differences appear, they are a function of some disparity between the stimulus fields.

Another method, which compared the stimulus windows in peripheral vision (hence hemispherically) was to affix a temporary fixation spot 3^{o} to the left of the LVF window and one 3^{o} to the right of the RVF window. The observer would, for a block of trials, fixate the central fixation spot while presentations were flashed up for example in the RVF window, thus testing the left hemisphere to threshold on this window. The observer would then fixate the temporary fixation spot to the left of the LVF window while trials were played in it, again testing the left hemisphere. Analogous combinations tested the right hemisphere on the two windows. In this case, disparities in the two results for a particular hemisphere would reveal differences in the stimulus fields. As in the experiment proper, binocular vision was used during these checks. Statistical analysis of the results of these tests revealed no significant differences in the thresholds set in the two stimulus fields. On the contrast scale, LVF score = 21.11, RVF = 20.94. $t=1.00$, $df=10$.

It may therefore be safely accepted that the results reported in this experiment reflect the subjects' processing capacities, and cannot be attributed to an artefact of stimulus inequality.

In addition, the luminescences of the windows under constant projector illumination with the stimulus discs rotating were measured at equal neutral density disc readings using an SEI Photometer. No differences in the luminances of the two windows could be measured. However,

no difference in luminances could be measured using the photometer over a fairly wide range of contrast settings on the discs (see results section), despite the clearly visible contrast change. Consequently, we set no great store by this mechanically measured extra check.

Subjects

The 20 subjects were 10 adult males (mean age 24.5 years, max 34 years, min 19 years); and 10 adult females (mean age 19.1 years, max 20 years, min 18 years). All were right handed as measured by the handedness questionnaire, and all had normal or corrected vision. Of the males, seven were undergraduate students, one a research student, one a research assistant, and one a lecturer, all at St. Andrews University; all the females were undergraduate students at St. Andrews University. Subjects had volunteered to take part in an experiment in visual perception.

The Staircase Method of Threshold Determination

The psychophysical method used in the experiment was the "Staircase Method" (Cornsweet, 1962; Kelly & Savoie, 1973; Rose et al, 1970); in earlier writings termed the "Up and Down Method" (Dixon & Massey, 1957; Wetherill & Levitt, 1965). In this technique, the subject's threshold is approached by setting the next stimulus level to be presented on the basis of his previous responses. In the simplest case, if the subject responds, "Yes, I see the stimulus," the stimulus level is decreased; if "no," the

level is increased. Thus from a particular starting point the level set moves quickly towards the subject's threshold and oscillates around it. The method is therefore economical in that after the first few trials, stimuli are always presented in the region of the subject's threshold.

There are, however, disadvantages with this simple version. Even an initially naive subject will quickly realize that when he answers "no," the stimulus intensity is increased (conversely for "yes"), so it is possible for him to respond so as to maintain his "threshold" at some easily discernible level. It is also possible, knowing the rule, to give "perfect" data while paying no attention to the stimuli. In addition, a subject may perseverate with a particular response (especially after the initial run from the starting point which is usually well above or below threshold); or, later in the sequence, anticipate his next response on the basis of his previous judgments.

To eliminate these sorts of effects, it is necessary to modify the method somewhat. Cornsweet (1962) suggests running two staircases each beginning from different starting points (the double staircase method). During the experiment, presentations are made from each staircase at random and stimulus levels on each staircase are set on the basis of responses to previous presentations on that staircase only.

As the subject has no way of knowing from which staircase a trial will be presented, he must attend to the stimuli to give meaningful data. Thus two staircases, one starting from a high and the other from a low stimulus level would tend towards threshold and oscillate about it.

Another adaptation of the staircase method incorporates a forced choice procedure. In general the subject is obliged to choose the interval in which the stimulus was presented from k alternatives. Here, also, the subject must attend to the stimuli to give meaningful data. Commonly in practice, k = 2 (the subject chooses one of two alternatives).

In this case, if the subject makes an incorrect response, the experimenter may assume that the stimulus was below threshold and increase the stimulus level for the next presentation on that staircase. However, if he responds correctly (since the subject is "forced" to make a decision), the experimenter may not safely assume that the presentation was above threshold as the subject can choose correctly half the time merely by guessing. Therefore two correct responses are required before the stimulus level is reduced.

The problem of step size in the staircase is discussed by Cornsweet (1962) who recommends the use of logorithmic steps for psychophysical investigations and suggests that step size should be such that fewer than five like responses are made before a reversal in the

simple staircase. If steps are too large, the staircase merely oscillates above and below threshold giving no precision; if the steps are too small, many trials may be required before a reversal occurs with unnecessary precision gained at the cost of numerous trials. Dixon and Massey (1957) recommend stimulus steps equal to the differential threshold. However, this is frequently not known by the experimenter so in practice convenient step size is usually established in pilot studies. The staircase method is most efficiently utilized when started from a point not too distant from threshold, in which case few trials are required before responses begin to alternate between correct and incorrect in the region of the threshold. For this reason, in addition to establishing rough thresholds in pilot studies, experimenters have frequently used large steps for the initial few presentations before switching to smaller steps when they have some indication that they have reached the subject's threshold (e.g., he makes his first incorrect response).

A staircase may be terminated after a certain number of "runs", i.e., a sequence of like (correct) responses followed by an unlike response (wrong). A run is part of a staircase between including adjacent tuning points. In the case of a simple staircase this would typically take the form of '''x (one run), and '''xx' (2 runs). (' indicates a correct response; x indicates an incorrect one).

Alternatively, a staircase may be terminated after a fixed number of trials.

Although Wetherill and Levitt (1965) advise using a fixed number of runs as the criterion for ending a staircase, the problem with this rule is that the experimenter cannot precisely predict how many experimental trials this will require. This is important if he wishes for example to run two staircases concurrently (e.g., one for each cerebral hemisphere) and wishes to present the same number of trials to each hemisphere to control for fatigue and practice effects. Cornsweet (1962) suggests that 20-25 trials will produce a fairly reliable result when using the staircase method, and Rose et al (1970) in their computer simulation of the staircase method show that running staircases for 25, 50, or 200 trials affects the mean threshold estimate only slightly. However, when the number of trials is increased, the standard deviation of the estimate is reduced, e.g., in the forced choice case a 28% decrease in the S.D. is obtained when the number of trials is increased from 25 to 50. They also show that running two staircases of 25 trials (as is often done in practice) is less variable than running one 50 trial staircase in the forced choice case.

In computing the threshold value, the first few trials, i.e., those leading from experimenter's arbitrary starting point towards the threshold, should be discarded since they usually reflect the experimenter's guess at

where the threshold lies rather than where subsequent data points indicate it to be.

Wetherill and Levitt (1965) compute the threshold by averaging peaks and valleys of the staircase. Rose et al (1970) simply average all points on the staircase after eliminating the initial trials.

In the experiment to be reported, a forced-choice double staircase was employed. An independent staircase was run for each hemisphere, trials from each staircase being presented randomly to the subject during a viewing session. The constraint being that the same number of presentations were made to each hemisphere.

As noted earlier, stimuli were displayed in two small viewing windows, positioned such that when the subject was looking at a central fixation spot, information was directly available to only one of the cerebral hemispheres. A stimulus presentation consisted of motion up or down in one window.

The subject was asked to push the response switch up if he perceived the motion as upwards, conversely for downwards motion, and guess if he was uncertain. Hence, a "forced choice" situation. Each staircase was run according to the following rules: The contrast level is increased on the next trial for (a) a wrong response, (b) a correct response followed by a wrong response; and decreased for two sequential correct responses. This sets

the threshold close to the 75% point on the psychophysical function (actually 0.7071, Wetherill & Levitt, 1965).

Pilot studies indicated that one (logorithmic) unit on the calibrated neutral density discs yielded staircases of a suitable structure when operated in the region of the subject's threshold.

During the experiment, presentations to each hemisphere were begun at the same high contrast level where practice trials indicated that the subject had no difficulty in detecting the direction of motion. In order to bring the stimulus levels quickly to the subject's threshold, the initial presentations of the staircases followed rules which differed from those of the staircase proper. For the first five trials on each staircase, the contrast was decreased by two logarithmic units and was decreased after each correct response. This rule quickly moved the presented contrast to a level which pilot studies indicated was around threshold. If the subject made no errors during this series, the sixth presentation was made at the same contrast level as the fifth, and the main staircase rule now followed. If, however, the subject made an incorrect response on a particular staircase during the first five trials, the main staircase rule was immediately introduced and the contrast increased by one unit for the next trial.

If not already at this error contrast level, the other hemisphere's staircase was allowed to rise to it and

then the main staircase rule started, i.e., two correct responses were required at this level before the contrast was decreased by one unit; if already above this contrast level, the main staircase rule was begun at the achieved level. Throughout subjects received no feedback as to whether or not they had responded correctly to each presentation.

The first five trials of each staircase were not used in the computation of the subject's threshold. To keep the number of presentations constant for each hemisphere to control for fatigue and practice effects, it was decided to terminate the staircases after a fixed number of presentations rather than after so many "runs." Pilot studies indicated that subjects could comfortably complete 40 responses before requiring a rest. Employing the double staircase method, this generated two staircases (one for each hemisphere) of 20 trials. After a short rest, a second series of 40 trials, again commencing with the presentation of stimuli at high contrast was run according to the same rules, which yielded another pair of staircases.

During the experiment, subjects responded with the same hand, e.g., the left, for the entire first block of 40 stimulus presentations. He was then given a 5 to 10 minute break during which time he could rest and stretch. The staircases for the second block of 40 presentations were now completed with the subject responding with his

other, e.g., right, hand. In the results section, the first block of 40 stimulus presentations is designated "Trial 1," and the second, "Trial 2," with the mean contrasts calculated for each staircase labelled accordingly. The hand which the subject used first was assigned in a pseudo-random fashion, the constraint being that 10 subjects, 5 male and 5 female, responded first with their left hand and the other half of the subject population responded first with their right hand.

Following the recommendation of Rose et al. (1970) the subject's threshold was calculated for each staircase by taking the mean of contrast levels set (eliminating the first five).

Response sheets

Data were collected during the experiment on pre-prepared recording sheets on which were printed, for each of the 40 presentations, the direction of motion and the hemisphere to which the stimulus was to be presented, i.e., up left (UL); up right (UR); down left (DL); down right (DR). These direction/hemisphere presentations were made in a pseudo-random order, the constraint being that each sheet contained 10 presentations of each of the four combinations.

To eliminate the possibility that one particular order of presentations would bias the results, five different sequence sheets were used in the experiment, though any particular subject received trials from

identical sheets for each run to threshold in order to balance the runs. Though the subject was not aware of this, he would receive the same trial sequence, e.g., the one on sheet 5 when using his left hand to respond in the runs to threshold; and after the break when using his right hand, he would again be presented with the sheet 5 sequence. Thus, the two blocks of trials are directly comparable with respect to practice or fatigue effects.

Responding hand, presented contrast, and whether the response was correct or wrong, were noted on the response recording sheet for each trial.

Procedure with subjects

Right handed subjects were recruited as participants in an experiment on visual perception, which including a half time break, would take about 3/4 of an hour. On arrival in the experimental room, they were informed that they were about to assist in an investigation of motion perception.

The subject was then seated in his viewing position and the two stimulus presentation windows were pointed out. He was told that during the experiment random dot shadows, which would flow either up or down during a particular stimulus presentation, would be cast in the windows. Motion would be presented in only one window per stimulus presentation but the window in which motion would appear would be randomly determined.

In the pre trials and throughout the experiment, the subject viewed the stimuli binocularly.

The apparatus was activated and the subject asked to look directly at one of the viewing windows where a high contrast stimulus in motion was presented. This was repeated for the other window and the subject directly viewed a number of such trials, observing both windows.

The subject was told that during the experiment, it would be his task to detect the direction of motion and communicate this to the experimenter by means of the switch which he was now asked to activate. If the motion appeared to be in an upwards direction, he should move the switch up (away from him); if the stimulus appeared to move downwards, he should move the switch down (towards him), irrespective of the stimulus window in which motion appeared. He was told that moving the switch would communicate his response electronically to the experimenter. It was important to respond as quickly as possible, but he should try to be correct rather than fast.

It was pointed out to the subject that he was not being asked to report on which side motion had occurred, merely to detect its direction.

He should always be focused on the fixation spot during stimulus presentations, one second prior to which the fixation spot would light up. He should not attempt to guess on which side a stimulus would be presented or

flick his eyes over to where motion had occurred. Fixation on the spot was essential in order to obtain meaningful data from the experiment.

To ensure that his head was held rigidly in the correct viewing position, a bite bar would be made. The pre-prepared aluminium bite bar covered in dental wax was now dipped in very hot water, clamped rigidly in place, and the subject bit an impression while focussing on the fixation spot. The wax was allowed to harden while the subject was informed that during the experiment he need not bite the bar continuously, but only when a stimulus presentation was due and while it was being presented.

During the experiment, he would wear headphones over which white noise would be played. The white noise would be dipped as a signal that a trial was due and he should bite the bar and fixate the spot.

The subject now viewed a number of high contrast stimulus presentations, wearing the headphones, biting the bar, fixating the spot and responding to stimuli using the hand he was due to use first in the experiment. All stimulus configurations, e.g., up left, down right, etc., which the subject would receive during the experiment were presented randomly in these trials.

When the experimenter had assured himself that the subject was familiar with the task, he terminated the practice session, the subject removed his headphones and questions which the subject raised were now clarified.

The subject was informed that during the experiment proper, the stimulus contrast would be reduced and that it would become increasingly difficult for him to correctly detect the direction of motion.

Each stimulus would be presented only once, so in cases where the subject was uncertain of the direction of motion, he should guess on the basis of the stimulus information, but should do so as quickly as possible.

After each response, he could relax until the white noise was dipped to signal the next stimulus presentation.

The subject now received a brief recap of his instructions, being particularly reminded to fixate on the spot during stimulus presentations. He was asked respond with the designated hand, replace the headphones and the experiment proper begun.

When the subject had completed 40 responses, he was given a 5-10 minute break, during which he could rest his eyes, and stretch. After the break, he completed the second 40 presentations responding with his other hand.

The subject now filled out the handedness questionnaire.

The sequence of events for a stimulus presentation during the experiment may be summarized as follows: [The experimenter has just noted the previous response and the subject is resting between stimulus presentations.]

The experimenter consults the response sheet to see which hemisphere is to receive the next presentation and what the direction of motion is to be.

From the recorded data, he reads off the previously set contrast levels for the stipulated hemisphere, notes whether responses at this contrast level have been correct or incorrect, and obeying the staircase rule, sets the neutral density disc to the next contrast to be presented and records this on the data sheet.

If necessary, he flips the pivoted flap to occlude the appropriate light vent and switches the motors to set one stimulus disc rotating in the required direction.

He then dips the white noise in the subject's headphones. This indicates to the subject that a presentation is due and he should bite the bar, fixate on the spot and grasp the response switch with the appropriate hand.

The experimenter now triggers the electronically timed stimulus display: the fixation spot lights up for 1 sec at the end of which time the projector flashes on for 100 ms illuminating the rotating disc.

The subject observes the stimulus display and moves the switch in the direction which the stimulus appears to move. This response is relayed to the experimenter's display.

The subject now relaxes before the next trial, while the experimenter records whether the subject's response is correct or incorrect.

This cycle now repeats.

When the experiment was over, its purpose was explained to subjects who were interested. The fact that the experiment was investigating the relative perceptual capabilities of the left and right cerebral hemispheres was now revealed. Diagrams of the visual system and cerebral hemispheres were drawn to illustrate how stimuli presented in the left visual field window went directly to only the right hemisphere, and conversely for the right visual field window.

The left hemisphere's linguistic superiority and the right hemisphere's perceptual superiority (in humans) was discussed, and the possible exceptions for left handers noted.

Before leaving, the subject was thanked for his participation in the experiment and invited to recruit friends as subjects, but not to discuss the hemispheric nature of the study with them prior to their completing the experiment.

Luminance Levels of Stimulus Fields

As described more fully earlier in the apparatus and procedure section, the stimulus fields were illuminated on the subject's side, from above and below, by the diffused light from two filament strips.

The movement stimuli were the shadows cast on the viewing windows by 100 ms flashes from the projector.

The contrast of the stimuli was reduced by attenuating the light from the projector with neutral density discs.

The primary measure in the experiment was the different contrast thresholds independently arrived at for each of the cerebral hemispheres of each subject. This threshold was determined using the staircase method.

Contrast values for stimulus presentations were taken from calibrated neutral density discs, with higher values representing lower contrast (or greater sensitivity on the part of the subject).

In the experiment, the threshold contrasts obtained ranged from 8.33 to 20.87, with a mean for all subjects of 14.45.

The corresponding luminances of the stimulus windows were measured from the subject's viewing position with an SEI Photometer.

These readings first measured the luminance of the windows without illumination from the projector, then with the stimulus discs rotating as they did in the experiment and with the projector switched on continuously (to enable photometer readings to be taken). The latter measurements were taken at the neutral density disc values set in the experiment.

The luminance values listed in the table are the means of a number of readings taken at each neutral density disc scale value.

Although there was a clearly visible (to the experimenter) change in contrast between the highest contrast set and the mean, no change in luminance was measurable using the photometer. However, the luminance of the lowest contrast was measurably different by a small amount.

There were no measurable differences in luminance between the two viewing windows at the same contrast settings.

Values

Luminance of LVF or RVF stimulus window with projector off = 1.00 log ft lambert. With projector on continuously and stimulus discs rotating:

Contrast reading from neutral density disc	Luminance (log. ft. lamberts)
8	1.075
15	1.075
21	1.025

Results: Experiment One

Four threshold contrast scores, one from each staircase (and consequently each hand/hemisphere combination) were calculated (as described earlier) for each of the 20 subjects.

Hemisphere		Left			
Hand		Left		Right	
Trial	Sex	Mean	SD	Mean	SD
1	M	14.89	1.41	12.09	1.40
2	M	14.76	2.56	15.09	1.87
1	F	13.85	3.24	15.88	2.66
2	F	15.12	3.73	14.96	4.15

Hemisphere		Right			
Hand		Left		Right	
Trial	Sex	Mean	SD	Mean	SD
1	M	14.11	1.52	12.07	1.46
2	M	15.31	0.78	15.65	2.75
1	F	12.15	2.84	13.70	3.32
2	F	15.55	4.19	15.93	2.63

Table 3.A.

Experiment One. Summary data. Contrast thresholds across all subjects. Males (n = 10) and Females (n = 10)

The convention adopted in this and subsequent Tables and Figures is that data designated Left and Right and "Hemisphere" are responses to right and left visual field stimuli, respectively.

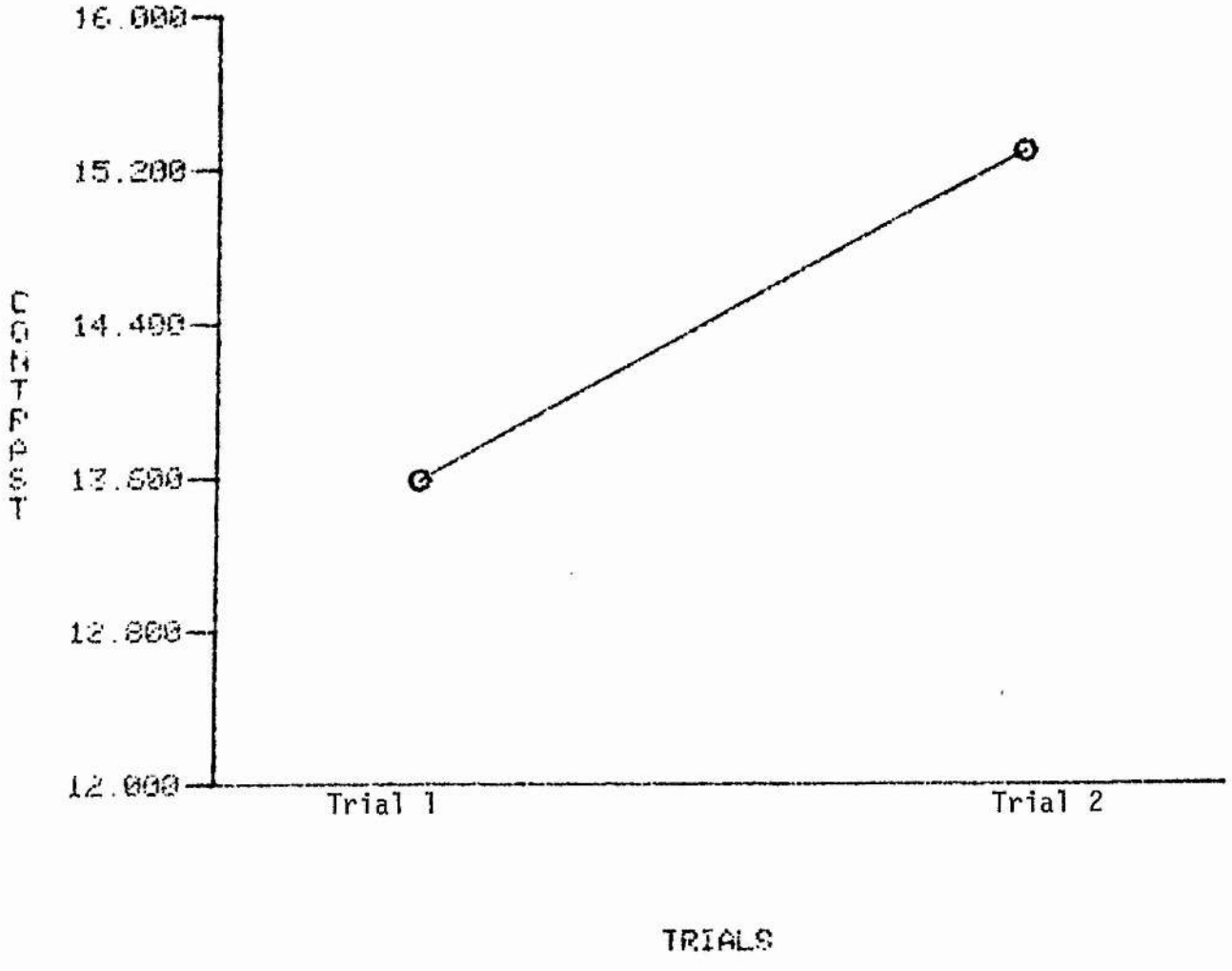
An analysis of variance was performed on this data to test for statistically significant effects. The within subject variables were hemisphere (left and right); hand (left and right); and trial (one and two). The between subject variable was sex (male and female).

The overall mean threshold contrast was 14.45.

Since subjects changed responding hand at the end of trial one and used their other hand for trial two, it is not statistically legitimate to examine hands x trials effects.

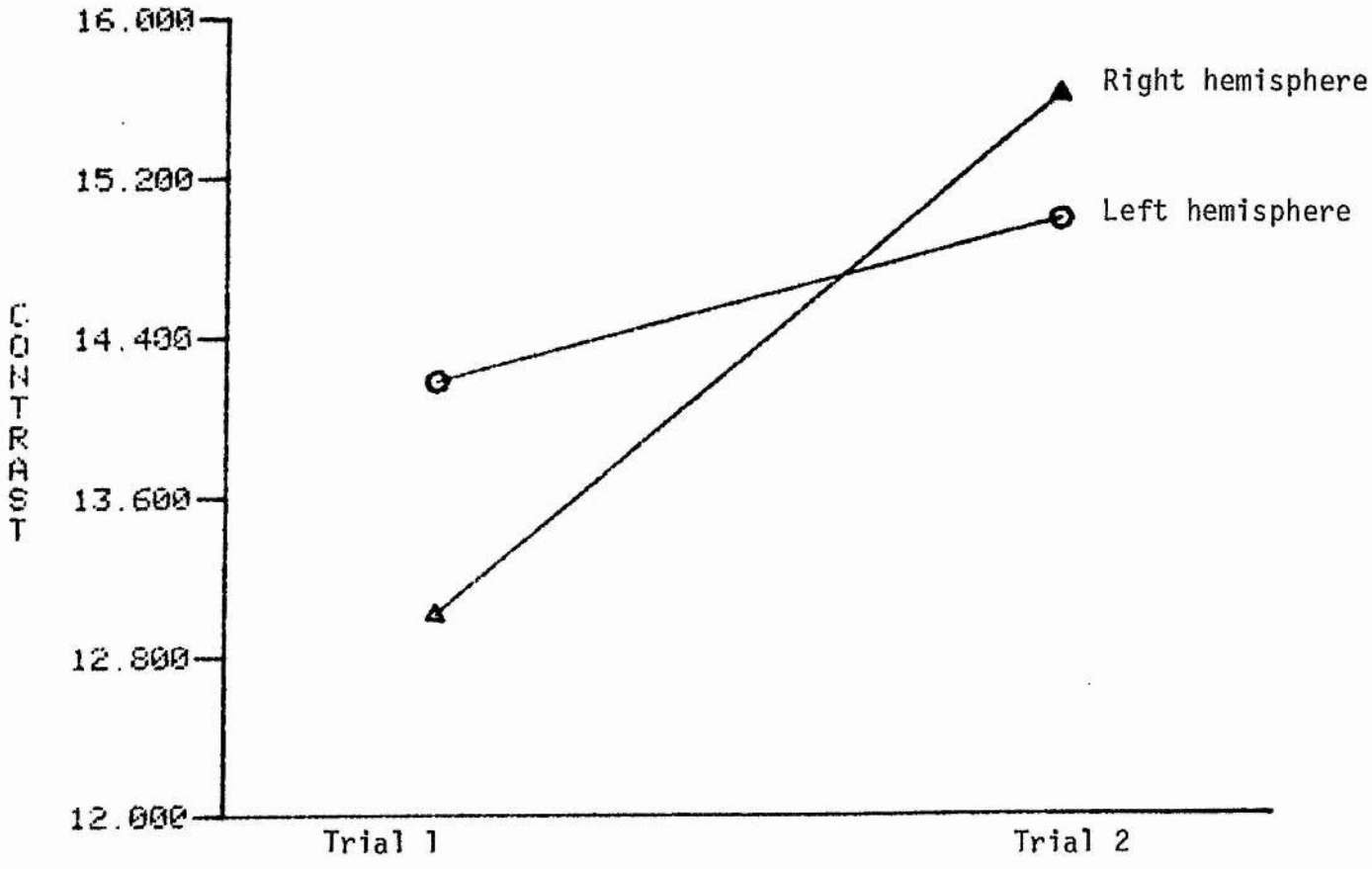
There were no significant main effects for hemisphere; (left 14.58 right 14.31); hand (left 14.49 right 14.42); or sex (male 14.25 female 14.65). Trials was significant $p < .005$. Subjects were more sensitive during trial two, setting a mean threshold contrast of 13.59 for trial one and 15.30 for trial two, Figure 3.5. Interaction effects: nonsignificant were hemisphere x hand; hemisphere x sex; hand x sex; and trials x sex. However, hemisphere x trials was significant, $p < .01$. See Table 3.1, Figure 3.6. This effect is largely accounted for by the great increase in sensitivity of the right hemisphere between trial one and trial two, which also accounts for a large part of the main effects for trials. Post hoc t tests showed that the right hemisphere was significantly ($p < .05$) less sensitive than the left hemisphere for trial one, but improved in trial two to become nonsignificant superior. t-tests also indicated that the right hemisphere improvement between trial one and trial two was significant at $p < .001$, whereas the left hemisphere

FIGURE 3.5



Experiment One. Real motion. Increase in threshold contrast (log units) over trials.

FIGURE 3.6



Experiment One. Difference between the cerebral hemispheres (ie stimuli presented to the contralateral VFs) in change in threshold contrast over trials.

did not improve significantly. The triple interactions hemisphere x hand x sex and hemisphere x trials x sex were nonsignificant.

Seventeen of the twenty subjects (85%) improved their right hemisphere score between trial one and trial two; whereas ten (50%) subjects improved their left hemisphere score. The three subjects who showed a right hemisphere decrement between trials one and two also showed a left hemisphere decline in performance.

The mean right handedness score for males was 2.28, for females 2.25. The overall handedness mean was 2.26 with a standard deviation of .40.

Table 3.1

Threshold Contrast

	Left Hemisphere	Right Hemisphere
Trial 1	14.18	13.01
Trial 2	14.98	15.61

Discussion

The measure of hemispheric sensitivity was the threshold contrast at which the direction of the moving stimuli could be correctly identified. This was independently set for each visual field, using the forced choice double staircase method, at close to the 75% point on the psychophysical function

(Wetherill & Levitt, 1965). Note that higher scores denote lower contrast and therefore greater sensitivity.

The hand which the subject used to respond had no effect on the contrast threshold set. This is not surprising, as on this measure the hand was merely being used to express the decision arrived at by the visual system. Errors are not a function of responding hand. Also, the nonsignificant hemisphere x hand interaction indicates that no more "noise" occurs in the response system irrespective of whether an ipsilateral or contralateral hand-hemisphere combination is used.

There was no overall difference between the sexes for the detection of real motion at low contrast. And no hemisphere x sex interaction. On the basis of the previously reported male superiority on numerous visuo spatial tasks, reviewed by Harris (1978), one might have expected a male superiority in this experiment, or perhaps a hemisphere x sex interaction. However, neither effect was observed. Also there was no significant difference between the sexes in their improvement over trials (sex x trials n.s.), and no sex x hand interaction.

Trials was significant at $p < .005$, Figure 3.5. Subjects improved considerably between trial one and trial two, indicating an increase in sensitivity for the second block of stimulus presentations.

Hemisphere x trials was significant at $p < .01$. The predominant aspect of this interaction is the dramatic improvement of the right hemisphere between the first and

second blocks of presentations. This also contributes substantially to the main effect for trials. t-tests showed that the right hemisphere improved significantly ($p < .001$) between trial one and trial two, while the left hemisphere did not. In trial one, the right hemisphere was significantly inferior to the left hemisphere ($p < .05$), while on trial two it was nonsignificantly superior, Figure 3.6.

In addition, seventeen of the twenty subjects improved their right hemisphere scores between trials one and two, whereas only ten showed a corresponding left hemisphere improvement. An overall fatigue effect may have occurred for the three subjects who did not increase their right hemisphere scores, since they also showed left hemisphere decrement over trials.

The hemisphere x trials interaction suggests that the detection of the direction of motion at low contrast is a task which the right hemisphere can "learn" and consequently improve its performance, while the left hemisphere does not improve significantly with practice. Previous experimental and clinical research indicates that the right hemisphere is especially able to deal with visuo-spatial tasks. It is possible that in this experiment it shows this facility by becoming attuned to the stimulus parameters which will result in increased response accuracy. However, since the right hemisphere performance is poorer than that of the left during trial one and superior for trial two, the explanation for the hemisphere x trials interaction may be more complex.

It should be recalled that all subjects were right handed and presumably left hemisphere dominant for language. It may be that despite the visuo spatial nature of the present task, the subjects' "everyday" cerebral dominance is still an influencing factor. From this conjecture and an analysis of reaction time data, one may suggest a number of possible processing strategies:

During both trials one and two, the left hemisphere when it detects motion but is uncertain of the direction, makes its own guess, because it is the dominant hemisphere, or because it has understood the linguistic experimental instructions which specify that each stimulus will be presented only once and in one visual field. Thus the left hemisphere always decides on the basis of the best available visual trace.

During trial one, the right hemisphere, when it is uncertain of the direction of presented motion, may not immediately respond. In this situation, assuming:

1. That the left hemisphere finally responds, then, (a) when the right hemisphere does not respond, the left simply guesses; (b) when the right hemisphere does not respond, the left sends across the corpus callosum to the right in an attempt to retrieve the now degraded/partially forgotten visual trace on the basis of which the left makes a response.

2. That the right hemisphere finally responds, then, (a) the right hemisphere waits for the "dominant" left to respond. When the left does not, the right must now respond on the basis of a degraded/partially forgotten visual trace; (b) the right hemisphere sends across the corpus callosum to the left hemisphere for corroborating information about the direction of

motion. When none is returned, it must then respond on the basis of its now degraded/partially forgotten visual trace.

All subjects may not employ the same strategy. However, by trial two the subject realizes that his trial one strategy is inefficient, and during trial two each hemisphere is making its own decisions independently.

One would think that it should be possible to test these explanations by collecting reaction time data. In practice, however, this was not rewarding. At the low threshold contrasts used in the experiment, judgments were fairly difficult and extremely slow. Correct RTs were around 1,200 ms and there were no statistically significant effects. The mean incorrect RT was around 1800 ms. There was a highly significant hemisphere x trials effect for incorrect RTs. During trial one, the right hemisphere (incorrect) RT was 800 ms longer than the corresponding left hemisphere RT. While during trial two, the incorrect RTs of both hemispheres did not differ significantly. The explanations offered for the contrast data were suggested by these results. However, a difference of 800 ms, could accommodate considerable neural activity.

Bertoloni et al. (1978) have shown that the right hemisphere gives faster reaction times in a task in which the velocities of stimuli have to be discriminated.

Trevarthen and Sperry (1973), while finding that human commissurotomy patients could cross integrate lateralized movements, also obtained evidence which suggested "that visual

attention processes are more right-brained for perception of large-scale peripheral stimuli lasting several seconds."

We have observed, for the detection of the direction of low contrast movement, disparities in hemispheric performance. These are characterized not by a simple right hemisphere superiority, but by a right hemisphere improvement between the first and second blocks of trials.

This, in conjunction with the studies cited, suggests that the right hemisphere is better able to become attuned to analysing the stimulus parameters which are relevant in making accurate decisions concerning real motion.

Consideration of the reaction time data suggests that the language dominant left hemisphere may be detrimentally affecting the right hemisphere's performance during trial one, but that by trial two each hemisphere is responding independently.

CHAPTER 4

Experiment 2. Hemispheric differences in the perception of apparent motion at low contrast

Introduction

Percepts of apparent motion may be produced by the appropriately timed onset and offset of two or more proximal lights. In the simple case of two lights, if light one is flashed briefly on then off and after a short time interval (the inter-stimulus interval, ISI), light two is flashed on then off, movement may be perceived between light one and light two. Whether motion is perceived between the lights depends on the interrelationship of a number of stimulus parameters: the brightness of the lights, their spatial separation, their temporal durations, and the duration of the ISI. With, for example, brightness, separation, and the duration of the stimulus lights held constant, at short ISI, the lights may appear to be flickering simultaneously with no associated movement; as the ISI is increased, partial movements from the position of light one towards light two may be observed; further increases in ISI result in improved motion percepts until optimal apparent movement is seen; at still longer ISIs, the lights appear to flash on and off in their actual temporal sequence with no associated motion (sequentiality).

The phenomenon of apparent movement has a long history of empirical study. Exner (1875) examined apparent motion induced by sequentially presented electrical sparks. Wertheimer's (1912) classic studies vastly extended the knowledge of apparent motion, while Korte (1915) and Neuhaus (1930) catalogued the effects of experimentally manipulating the stimulus parameters.

Since these pioneering experiments, researchers have extensively studied apparent movement, and probably more has been published on apparent motion than has been on the perception of real movement. Despite this, the nature of the relationsnip between apparent movement and real movement remains contentious. Many researchers consider that real and apparent motion are mediated by the same neural mechanisms (Wertheimer, 1912; Gibson, 1954; Gregory, 1966; Frisby, 1972). However, Kolers (1963, 1964, 1972) takes an opposing view. "The outcome of my studies was the finding that the neural mechanisms for the two types of perception must be quite different, because these identical perceptions seem to be constructed in the nervous system according to different rules" (Kolers, 1964).

Although it is likely that the same neural mechanisms are involved in the processing of both real and apparent movement information, it is however clear that certain perceptual effects which may be demonstrated in the apparent motion paradigm are not observable with real motion, and vice versa. Indeed, in the apparent motion

experiments to be reported, a more complex set of hemispheric dominance results were obtained than those observed for real motion. And the dominance effects for apparent movement were subject to changes dependent on the stimulus parameters.

The first apparent motion experiment to be reported examined hemispheric differences in the detection of the direction of apparent movement at threshold contrast. Stimulus parameters such as contrast and duration were chosen so as to make the experiment somewhat comparable to experiment one (real motion).

The stimuli used were pairs of enlarged photographs of a Julesz (1971) random dot pattern. Such patterns are ideal for use in hemispheric experiments since the stimulus shape to be identified in motion is an integral part of the pattern. When pattern pairs are presented sequentially with the area of dots defining the stimulus shape spatially displaced, motion of the "camouflaged" shape is readily perceived. Thus, prior to the presentation of the second pattern of the stimulus pair, the subject has no information as to the visual field in which motion will occur.

In experiment one, the data suggested possible response mediation by the verbal left hemisphere. To investigate this possibility, subjects were asked to report, <u>post experimentally</u>, whether their responses involved sub-vocal verbalization. One would predict that

subjects who employed sub-vocal verbalization would show less strong right hemisphere effects.

Apparatus and Procedure

The experiment was conducted in a windowless experimental room approximately 6 yds x 4 yds in size, the walls of which were painted matte black. The room was illuminated from the ceiling by three shaded 60 watt light bulbs, and by the experimenter's shaded angle poise lamp. Consequently subjects were light adapted.

Stimuli were presented in an Electronic Developments three field tachistoscope, the electronic unit of which could be programmed to switch on the stimulus fields of the optical unit either sequentially or simultaneously for the required stimulus presentation durations.

The three fields of the tachistoscope were utilized as follows: F1 (field one) and F2 were the stimulus fields, and Fb, the fixation field.

The brightness of the stimulus fields was also controlled by the electronic unit, and could be further reduced, as it was for F1 and F2 in this experiment, by placing neutral density gelatin filters in the optical unit fields. To ensure a uniform filtering effect, curvature was eliminated from the gelatin filters by sandwiching them between rectangles of clear perspex.

Disparities in the position of corresponding stimuli presented in F1 and F2, coupled with appropriate inter stimulus intervals between field presentations, yield

perceptions of apparent motion (Wertheimer, 1912; Korte, 1915).

When viewed in the tachistoscope, 1 in. on a stimulus card was equivalent to 3^{o} visual angle, the necessary displacement from fixation to ensure lateralization, and stimulus cards 6 in. x 4-1/4 in. were required to fit snugly into the tachistoscope card holders.

The Fb (fixation field) stimulus card was a 6 in. x 4-1/4 in. white card with a centrally positioned 1/8 in. diameter black fixation spot.

The four stimulus fields cards (cards 1 and 2 for F1 and cards 3 and 4 for F2), were made up from enlarged photographs of a Julesz (1971) random dot stereogram (see Appendix B). The enlargement resulted in items of texture being 1/14 in. x 1/14 in., or $.21^{o}$ x $.21^{o}$ VA in the tachistoscope. The stimulus cards were constructed by cutting out four identically patterned 6 in. x 4-1/4 in. rectangles, and eight identically patterned 1 in. x 1 in. squares from photographic enlargements of the stereogram. Two similarly orientated 1 in. squares were positioned with their central axis level with the central point of each 6 in. x 4-1/4 in. rectangle, one square with the mid point of its nearest edge 1 in. horizontally to the left of the central point and the other square with the mid point of its nearest edge 1 in. horizontally to the right (see Figure 4.1).

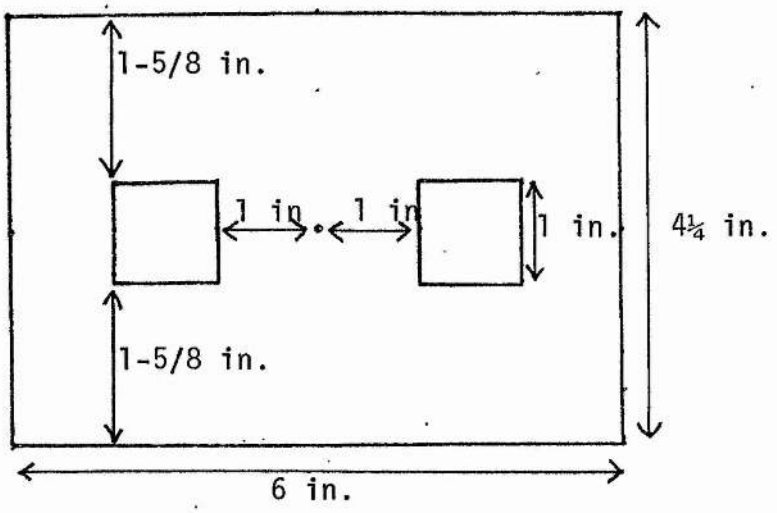


Figure 4.1 (Entire card is randomly textured.)

Experiment Two. Diagram of a stimulus card showing dimensions and position of displaced squares.

For card 3, the 1 in. squares were gummed securely in these positions; for card 1, the left hand 1 in. square was gummed in this position, but the right hand square was moved down (the card 1 item of texture and gummed there; for card 2, the right hand square remained in position and the left hand square moved down 1 item of texture; for card 4, both 1 in. squares were gummed on 1 item of texture lower than the squares on card 3. The stimulus cards were completed by gumming the 6 in. x 4-1/4 in. patterns onto similarly sized thin rigid cardboard.

Slight imperfections at the edges between the 1 in. squares and the backgrounds were painted out with black or white poster paint.

The positions of the 1 in. squares on the 6 in. x 4-1/4 in. backgrounds are shown schematically in Figure 4.2. For illustrative purposes, the displacements of the small squares relative to the fixation spot and each other are greatly exaggerated. The dot equivalent to the fixation spot on the stimulus cards in the figure did not, of course, appear on the actual cards. It is presented here as a reference point. Cards 1, 2, 3, and 4 are textured.

As can be determined from a consideration of the situation in which card 1 is presented in F1 and card 3 is presented temporally later in F2, under conditions which result in the perception of apparent motion, the 1 in. square in the left visual field (LVF) remains in the same

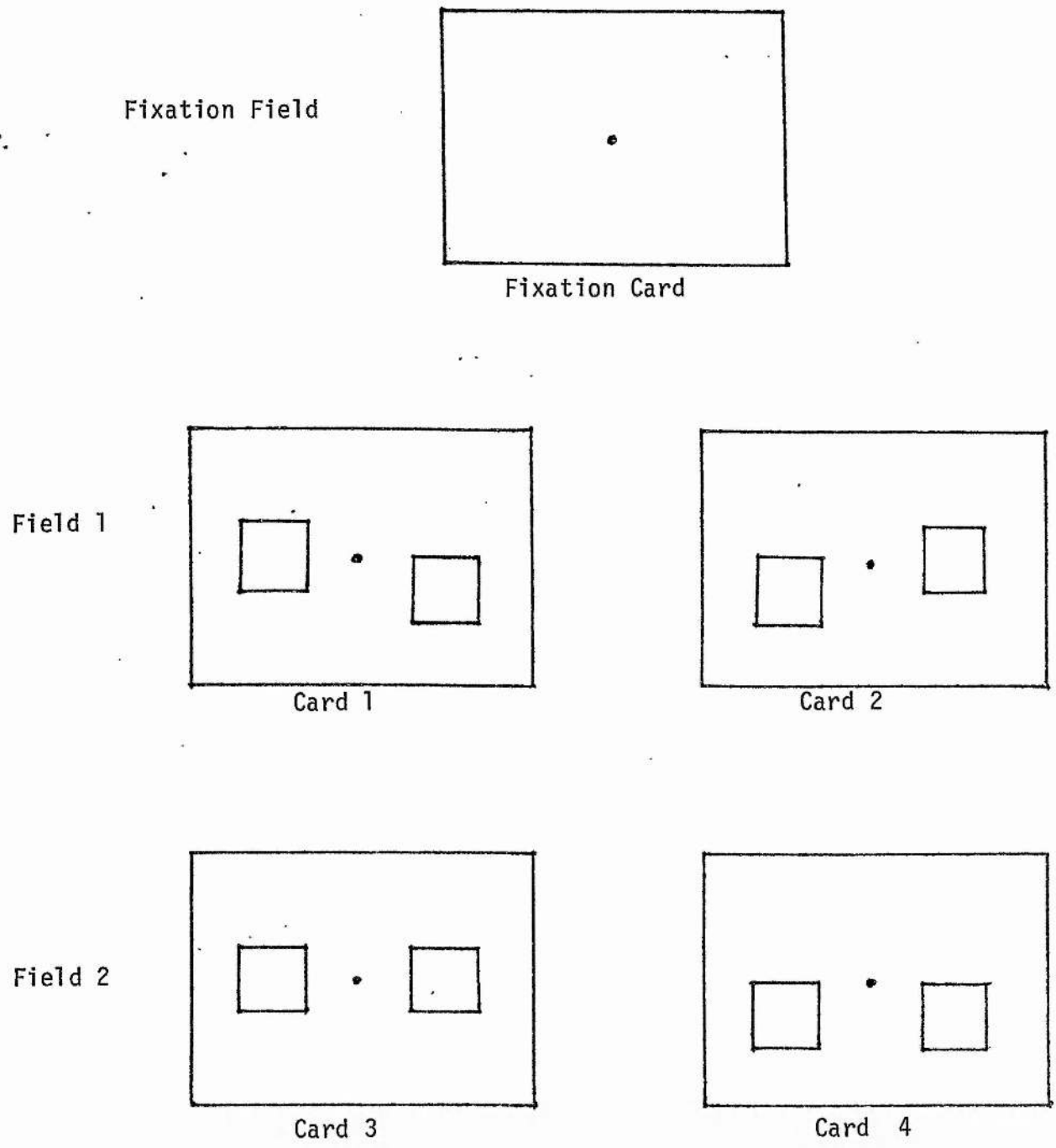


FIGURE 4.2 : Experiment Two. Schematic diagram of the squares' positions on each card. Placed in the tachistoscope field designated the card in field 1 (F1) optically occupied the same spatial position as a card in F2. With appropriately timed switches from F1 to F2, the displaced squares gave rise to apparent movement, while the spatially corresponding squares remained stationary.

position spatially so cannot be distinguished from the background, while the square in the right visual field (RVF) is displaced upwards spatially. This results, under optimum apparent motion viewing conditions, in the perception of a square moving upwards across the background in the RVF.

When a single card is viewed in the tachistoscope under constant illumination, the small squares are not distinguishable from the background and the cards appear as uniform random dot patterns. It is only when two cards are viewed in the appropriate temporal sequence that the small squares are differentiated from the background and perceived as being in motion. A card presented alone gives the subject no information as to the direction of motion or the side on which it will occur, it is only when the second card of the pair is presented that the square in motion is percieved.

With F1 always presented temporally prior to F2, the stimulus cards may be sequenced so as to produce the required direction of motion (up or down) in the appropriate visual field.

That is:

Table 4.1

Field 1 Card Presented	Field 2 Card Presented	Motion Direction	Motion Visual Field	Hemisphere Stimulated
1	3	up	right	left
1	4	down	left	right
2	3	up	left	right
2	4	down	right	left

In order to control for any properties of the stimulus cards which might have made a particular direction of motion more easily detectable in one field (e.g., a certain identifiable configuration of random dots), for part 2 of the experiment each card was rotated through 180^{o} (turned upside down) and replaced in the same card holder, and can be considered as occupying the same spatial position in Figure 4.2. This results in:

Table 4.2

Field 1 Card Presented	Field 2 Card Presented	Motion Direction	Motion Visual Field	Hemisphere Stimulated
1	3	down	left	right
1	4	up	right	left
2	3	down	right	left
2	4	up	left	right

As can be seen from comparisons of tables 4.1 and 4.2, the pairs of cards now produce the opposite direction of apparent motion in the "opposite" visual fields.

Half the 16 subjects (8 male and 8 female) received presentations with cards orientated as in table 4.1 and the other half as in table 4.2.

That is:

For Table 4.1:

two males commencing responding with right hand

two males commencing responding with left hand

two females commencing responding with right hand

two females commencing responding with left hand

Similarly for table 4.2.

It should be noted that during a single stimulus presentation, motion occurs in only one visual field. Properties of the stimuli precluded changing or even rotating the cards presented to a particular subject. It was noticed in pilot studies that very slight misalignments of the card pairs resulted in perceptions of motion of the entire background. Thus, it was necessary, prior to the running of each subject, for the experimenter to align the cards carefully to eliminate this effect. This was done visually by observing pairs of stimulus cards under conditions of optimum apparent motion and adjusting them by trial and error until swings in the background were eliminated. For this reason, it was also necessary to have the cards fit tightly into the card holders so

that they were not misaligned as the cardholder was slid across to e.g., present card 2 instead of card 1 in F1.

As was noted earlier, when viewed in the tachistoscope, 1 in. on a stimulus card was equivalent to 3^{o} visual angle (VA). Thus, the nearest edge of a moving square was 3^{o} VA from fixation, the furthest edge 6^{o} VA, and the center of the square $4\text{-}1/2^{o}$ VA to the left or right of fixation. Consequently with the subject binocularly fixating the central spot of the fixation card, the apparently moving small square was lateralized to either the left or right cerebral hemisphere (as was discussed in Chapter 2).

Fb remained on throughout the experiment, serving as a background field which attenuated the contrasts of the stimulus fields, and provided a constant fixation spot for subjects during stimulus presentations. The timing unit of the tachistoscope was programmed to trigger the fields in the following sequence: F1 is switched on presenting the stimulus card in F1 for 500 ms (Stimulus 1, S1), then off; Fb remains on alone for 1 ms (the inter-stimulus interval, ISI); F2 is switched on presenting the stimulus card in F2 for 100 ms (Stimulus 2, S2), then off; Fb remains on alone.

These durations remained constant for all subjects during the experiment. Note that until the onset of F2, there is no information as to on which side or in which

direction the motion will be, and the duration of S2 is 100 ms, well within the latency of eye movements.

A 1 kh tone, .75 sec in duration, warned subjects that a stimulus presentation was due. This tone was presented to subjects through stereo headphones which delivered sound of equal intensity to each ear. The headphones, which subjects wore throughout the experiment, also muffled the sound of tachistoscope field changes and other extraneous sounds. One sec. after the warning tone, a trial is presented.

An experimental presentation is represented in Figure 4.3 (not drawn to scale).

For this experiment, the independent measure was the contrast of S1 and S2, set in pretrials to each subject's individual threshold. For all subjects, Fb was set, using the electronic unit of the tachistoscope at max. brightness; while F1 and F2 were reduced to equivalent low brightness levels depending on the subject's threshold.

Pilot Studies - Selection of Stimulus Parameters

Pilot studies were conducted principally in connection with the making of the random dot stimuli and the selection of suitable values for stimulus parameters such as field durations and contrast.

These pilot studies were initially conducted with the experimenter triggering the tachistoscope, viewing the stimulus display and on the basis of these observations, adjusting the stimulus conditions appropriately. Once

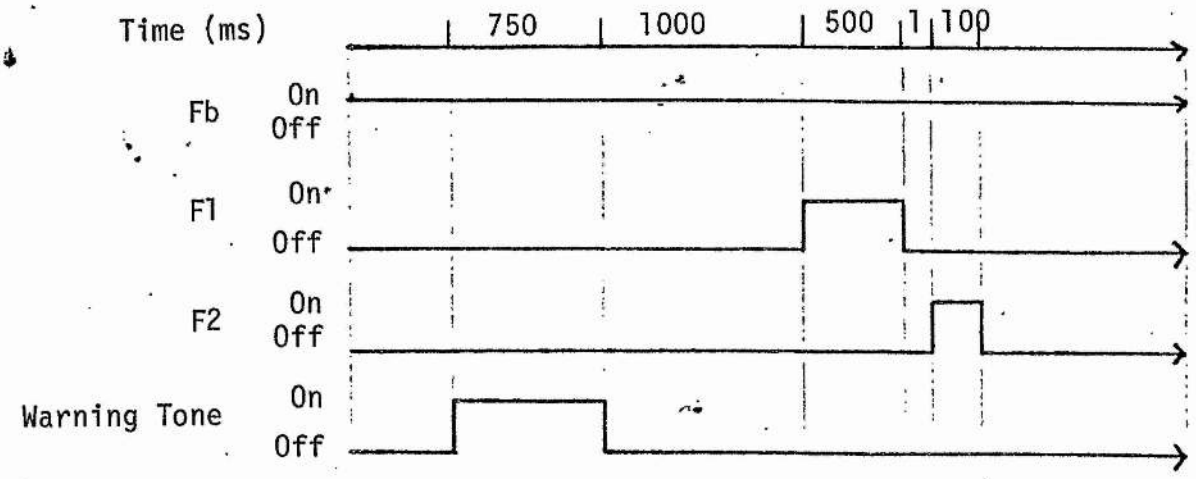


Figure 4.3

Experiment Two. Temporal sequence of events in an experimental presentation showing the on/off durations of the background field (Fb) and the stimulus fields (F1 and F2).

approximately suitable stimulus values had been found, assistants were recruited to act as subjects who provided feedback and suggestions in informal experiments. Finally subjects were run as in the experiment proper, and from their data, the stimulus conditions for the experiment were selected.

The nature of the study predetermined certain stimulus features, e.g., the moving stimuli had to be displaced at least 2.5^{o} visual angle from fixation to ensure lateralization, and the duration of the segment of the stimulus display which provided the visual system with motion information had to be within the latency of eye movements (approximately 150 ms).

It was found that if the relative displacement of the small squares on the stimulus cards was more than one item of texture, the direction of motion became ambiguous. Motion was clearly visible, but it was difficult to be constantly accurate in deciding which direction the small square was moving (as determined by the actual displacement on the stimulus card). This effect occurred both for direct foveal observation and for fixation on the central spot. For an actual displacement of say up, the motion sometimes appeared (to the experimenter) as up, sometimes down, and on other occasions as a brief downwards motion followed by an upwards motion.

For small square displacements of one item of texture, these effects did not occur for most stimulus values, and

especially for low contrast stimuli. Therefore displacements of one item of texture were used in the experiment. However, some subjects consistently saw motion in the "wrong" direction and were eliminated either in experimental pretrials, or if their overall experimental data did not differ significantly from chance in the number of correct responses.

(These effects of motion appearing to be in the wrong direction are discussed more fully in chapter 5).

It was proposed to look at hemispheric differences at threshold contrast. However, it was found that the contrast levels obtained by simply inserting the stimuli in the tachistoscope were too high. Consequently, the brightnesses of the stimulus fields were reduced by placing gelatin neutral density filters in the optical unit of the tachistoscope.

In an attempt to make the stimulus durations somewhat analogous to those used in experiment 1, the ISI was kept very brief (1 ms), and S2 equal to the duration of the stimulus display in Experiment 1 (100 ms).

As there were no electric motors running in this experiment, the white noise played through the headphones during Experiment 1 was dispensed with and replaced by a warning tone, sounded when a trial was to be presented.

On the tachistoscope, it is, of course, not possible to set different contrast levels for each visual field (or leave unadjusted a previously set contrast level in one VF

while a stimulus presentation is made in the other) as one could in Experiment 1. With the experimenter manually shifting the stimulus card holders and recording the data between each stimulus presentation, it was decided that the additional techistoscope dial changing required to run dual staircases as in Experiment 1 would cause excessive delays between stimulus presentations. This could result in the subject becoming bored or distracted between trials, and fatigued due to the extended experimental duration. It was decided therefore to set each subject's threshold in pretrials and leave this fixed for all his experimental stimulus presentations.

Apparatus and Procedure

As in Experiment 1, subjects were requested to respond to upwards motion by moving the switch (described in Experiment 1) up; and to downwards motion by moving the switch down, irrespective of which side the motion occurred. Again, the subject's response was communicated electronically to the experimenter.

In the experiment, subjects binocularly viewed 80 presentations divided into two blocks of 40 by a 5-10 minute break. They responded to the first block using one hand and to the second using the other hand. Half of the 16 subjects, 4 male and 4 male, first used their left hand, the other 8 subjects used their right hand first. Aside from this constraint, the hand which a subject would use first was randomly assigned.

Subjects received no feedback as to whether or not they had responded correctly to each presentation. However, during the rest break between blocks of trials they were reassured if necessary that their rate of correct responses was sufficiently high.

Stimuli were presented to the subject's left or right hemisphere in a pseudo-random manner. The constraint being that for each 40 presentations, 10 were up left; 10 up right; 10 down left; 10 down right, with the stimulus presented on a particular trial selected randomly from these options.

The data collection sheets used in Experiment 1 were used similarly in this experiment. On these sheets were printed the random presentations for the subject, and on the sheets the experimenter recorded the subject's responding hand; the contrast set; and whether the response was correct or wrong. As in Experiment 1, although the subject was not aware of this, he received the same random sequence, e.g., the one on sheet 3, for both blocks of presentations. Thus the blocks are again directly comparable with respect to practice or fatigue effects.

In the results section, the subject's first 40 responses (first sheet and hand) are designated "trial one." His second set of responses, "trial two."

For each stimulus presentation, the subject was required to make a response. If they were uncertain as to the direction of motion, they were obliged to guess as

quickly as possible. Hence, a forced choice paradigm was employed, in which it is possible to record 50% correct responses merely by guessing. Thus, an overall correct response rate of 52 out of 80 (X^2 sig 1 < .01 for fo = 51.5) is required to indicate that a subject is responding in a non-chance manner to the stimuli presented.

Apparatus and Procedure (Field Checks)

As in Experiment 1, visual field checks were conducted to ensure that stimuli of equal detectability were being presented to both cerebral hemispheres.

In this experiment, and in Experiments 3 and 4, since the same apparatus and stimuli were used, checks consisted of having an assistant foveally view the visual field in which motion was to occur.

Trials were presented as in the experiment proper, according to the schedule on the stimulus presentation sheet, at low contrast or brief stimulus duration depending on the experiment. Subjects were informed prior to a presentation in which VF motion would occur.

Checks were conducted prior to, during, and after experiments and in these checks the experimenter was assisted by four people, three of whom had participated in similar checks in Experiment 1. In addition, it was now possible for the experimenter to conduct checks himself since the tachistoscope could be triggered by the observer.

No consistent differences in the number of correct responses to each VF were noted, and a t test of the number of correct RVF vs LVF responses for observers over the three experiments was nonsignificant. LVF 75% correct, RVF 79% correct. $t=.97$, $df=9$.

Therefore, it may again be safely accepted that if visual field differences are observed in these experiments, the results are due to cerebral hemisphere differences and are not a consequence of discrepancies in the stimuli or apparatus.

Subjects

The 16 subjects were 8 adult males (mean age 20.6 years, max 23 years, min 18 years); and 8 adult females (mean age 19.3 years, max 21 years, min 18 years). All were right handed (see Results section) and had normal or corrected vision. Seven of the males were undergraduate students, one a post graduate student, and all the females were undergraduate students. All subjects attended St. Andrews University and had volunteered to participate in an experiment on visual perception.

Every subject run in the experiment gave a total number of correct responses which was significantly above chance. No one was eliminated from this experiment for being unable to correctly detect the direction of motion.

Procedure with Subjects

Right handed subjects were recruited as participants in an experiment on visual perception. On arrival in the laboratory, they were informed that they were about to

assist in an investigation of apparent motion. Subjects unclear as to what was meant by "apparent motion" were given a brief explanation with diagrams, citing the example of two light bulbs which flash on and off in sequence. The conditions under which motion between the bulbs would be observed were outlined. Neon advertising signs in which a shape appears to move were remarked upon as an everyday example.

The subject was then told that random black and white fields would be presented in the tachistoscope, and one of the stimulus fields was switched on continuously for the subject to view. Binocular vision was used throughout the experiment. He was told that during stimulus presentations, an area of the pattern defining a square would move either up or down either on the right or left of the central fixation spot. The subject was then shown the four stimulus presentations that would be used in the experiment, i.e., up-LVF; down-RVF, etc. During these presentations, he was asked to look directly at the moving squares and familiarize himself with the stimuli. The durations of the stimulus fields for these trial presentations were as for the experiment proper. However, F1 and F2 were at approximately maximum brightness, giving stimuli of high contrast and motion of clearly discernible direction.

It was explained to the subject that during the experiment his task was to detect the direction of motion of the stimulus and communicate this information to the

experimenter by means of the switch. If the motion appeared to be in an upwards direction, he should move the switch up (away from him); if the stimulus appeared to move downwards, he should move the switch down (towards him), irrespective of which side the motion appeared. He was told that moving the switch would communicate his response electronically to the experimenter. It was important to respond as quickly as possible but he should try to be correct rather than fast in his responses, as the number correct was the primary experimental measure. Each presentation would be made only once, so, if for a particular stimulus, he was uncertain of the direction of motion, he should make the best possible guess on the basis of what he had seen, again as quickly as possible. As he was responding by switch, there was no need to talk during the experiment. If, however, he moved the switch in the wrong direction by mistake, i.e., if he was sure of the direction of motion presented but had made the wrong response, he could correct this verbally (errors of this type were in practice infrequent).

He was told that the same number of moving stimuli would be presented on the left as on the right of the fixation spot, and that motion would only occur on <u>one</u> side for a particular presentation, but this was randomly determined.

It was emphasized to the subject that he should always be looking at the fixation spot during stimulus presentations and should not try to anticipate on which side motion would appear, or after a presentation flick his eyes to where the motion had occurred. Fixation on the spot during stimulus presentations was vital in order to obtain meaningful data from the experiment. To help ensure that he was focused on the fixation spot during stimulus presentations, he would hear a warning bleep through the headphones, when he heard this, he should fixate on the spot. The presentation would occur a second after the warning tone.

It was pointed out to the subject that he was not being asked to report on which side motion had occurred, merely to detect its direction.

He was told that he should respond to the first block of presentations using his left hand and to the second block using his right (or conversely according to the experimental randomization). The experimenter would remind him to change hands after the half time break.

It was now revealed to the subject that the contrast of the stimuli in the experiment proper would be much lower than those he had previously seen, in fact it was necessary to reduce the stimulus field contrast to a point where he would make some mistakes about the direction of motion.

The subject now wore the headphones (receiving the warning tone) binocularly observed the stimuli (fixating on

the central spot) and responded using the switch, all as in the experiment proper; while the experimenter reduced the contrast of the stimulus fields a little and presented one of the motion conditions at random. After the subject responded, this procedure was repeated with the stimulus fields' contrast being reduced on each random presentation until the subject made an error or hesitated considerably in his response, indicating uncertainty as to the duration of motion. When this occurred, more presentations were made with the contrast reduced or increased by small amounts until the subject's approximate threshold was ascertained. With this contrast level fixed,the subject received further presentations to verify that this setting was close to his threshold. These trials, typically totalling 10-12, served in a threshold setting capacity, as practice for the experiment proper, and presentations during which the experimenter could satisfy himself that the subject was following the instructions.

The subject was now asked to remove the headphones, was told that the contrast for the experiment proper would be set at that of the latter few presentations, then he viewed a few more random presentations during which he could raise for clarification any questions which he had concerning his task.

The subject was then given a resume of the sequence of events--"I will play you a bleep in the headphones, this will warn you that a trial is due, and you should fixate on

the spot. A trial will follow and you should push the lever up if the motion appears to be upward, down if the motion appears downward, guess on the basis of the presentation if you are uncertain. After you have responded, you can relax, while I note your decision and change the fields for the next trial. Then the sequence begins again. Any questions? Remember, up for upwards motion, down for downwards motion irrespective of side. Always fixate on the spot when a trial is due. Begin responding with your right/left hand."

The subject then replaced his headphones and the experiment proper was begun and run as described above. When he had completed 40 trials, he was told to stop and take a break. This rest period was typically 5 minutes or so. The subject then completed the next 40 trials responding with his other hand.

After completing the experiment, the subject filled out the handedness questionnaire and was additionally asked whether his responses had been mediated by sub vocal verbalization. For example, when responding to upwards motion had he said "up" in his head, etc., or had his response been "automatic" with no verbal component. This question was always asked post experimentally to avoid any possibility of influencing the subject's experimental approach.

As in experiment one, the purpose and theory of the experiment were now fully explained to the subject. He was

thanked for his participation and asked to recruit friends as subjects, but not to discuss the hemispheric nature of the task with them prior to their completion of the experiment.

Luminance levels of stimulus fields

As reported earlier in the apparatus and procedure section, Fb, the fixation field, a white field with a black fixation spot, was switched on continuously throughout experimental presentations, while the random dot stimulus fields F1 and F2, were flashed on to provide perceptions of motion.

The independent measure in this experiment was the contrast of the stimuli, set at each subject's individual threshold, and the dependent measure was the number of correct responses to stimuli presented to each cerebral hemisphere.

The contrast of the stimuli was attenuated by reducing the brightness of the stimulus fields using the % Intensity dials on the electronic unit of the tachistoscope, while Fb remained at max. It should be recalled that the brightness of the stimulus fields was also reduced by a constant amount using gelatin neutrol density filters.

The contrast for each subject's threshold was taken from the tachistoscope's % Intensity scale. The corresponding luminances of Fb plus, F1 or F2 were measured in log. ft. lamberts using an SEI photometer. The luminance

of Fb was measured as it was presented during the experiment, while the luminance of F1 (or F2) was measured at a white item of texture while switched on continuously over Fb.

The minimum % Intensity set by a subject was 15, the maximum 95, while the mean for all 16 subjects was 38.25.

When the luminance of the stimulus field was changed from 15 to 95, there was a clearly discernible change in stimulus contrast and a luminance difference easily measurable using the photometer. However, in the mid range, although the % Intensity scale seemed to produce a linear change in contrast (as observed by the experimenter), the luminance as measured by the photometer at 38.25 (approximately half way between 15 and 95), was 1.45 log. ft. lamberts rather than 1.40 log. ft. lamberts as might have been expected.

All luminance values presented are the means of a number of photometer readings taken at different white points on the stimulus fields and on various cards. The differences in luminance at other points on the % Intensity scale were so small that they could not be consistently measured using the SEI photometer.

Values

Field	% Intensity Setting	Luminance log. ft. lamberts
Fb	on alone at max	1.25
Fb(max) + F1 (or F2) at	15	1.30
"	38.25	1.45
"	95	1.50

Results: Experiment Two

Percent correct scores were calculated from the raw data for each hand/hemisphere/trial combination, giving four scores for each of the 16 subjects.

An analysis of variance was performed on this data to test for statistically significant effects. The within subject variables were hemisphere (left and right); hand (left and right); and trial (one and two). The between subject variable was sex (male and female).

Since subjects changed responding hand at the end of trial one and used their other hand for trial two, it is not statistically legitimate to examine hands x trials effects. The overall mean percent correct response rate was 84.45%.

There were no statistically significant main effects for hand, sex or trial. But hemisphere was significant at $p < .05$. Subjects gave higher mean percent correct scores using the right hemisphere, 88.125%; while the left

Hemisphere		Left			
Hand		Left		Right	
Trial	Sex	Mean	SD	Mean	SD
1	M	92.50	5.00	75.00	15.81
2	M	73.75	17.97	82.50	5.00
1	F	70.00	21.98	81.25	11.09
2	F	86.25	12.50	85.00	4.08

Hemisphere		Right			
Hand		Left		Right	
Trial	Sex	Mean	SD	Mean	SD
1	M	88.75	8.54	81.25	11.09
2	M	86.25	11.09	86.25	8.54
1	F	86.25	14.93	88.75	10.31
2	F	96.25	4.79	91.25	11.81

Table 4.A.

Experiment Two. Summary data. Percent correct across all subjects. Males (n = 8) and Females (n = 8).

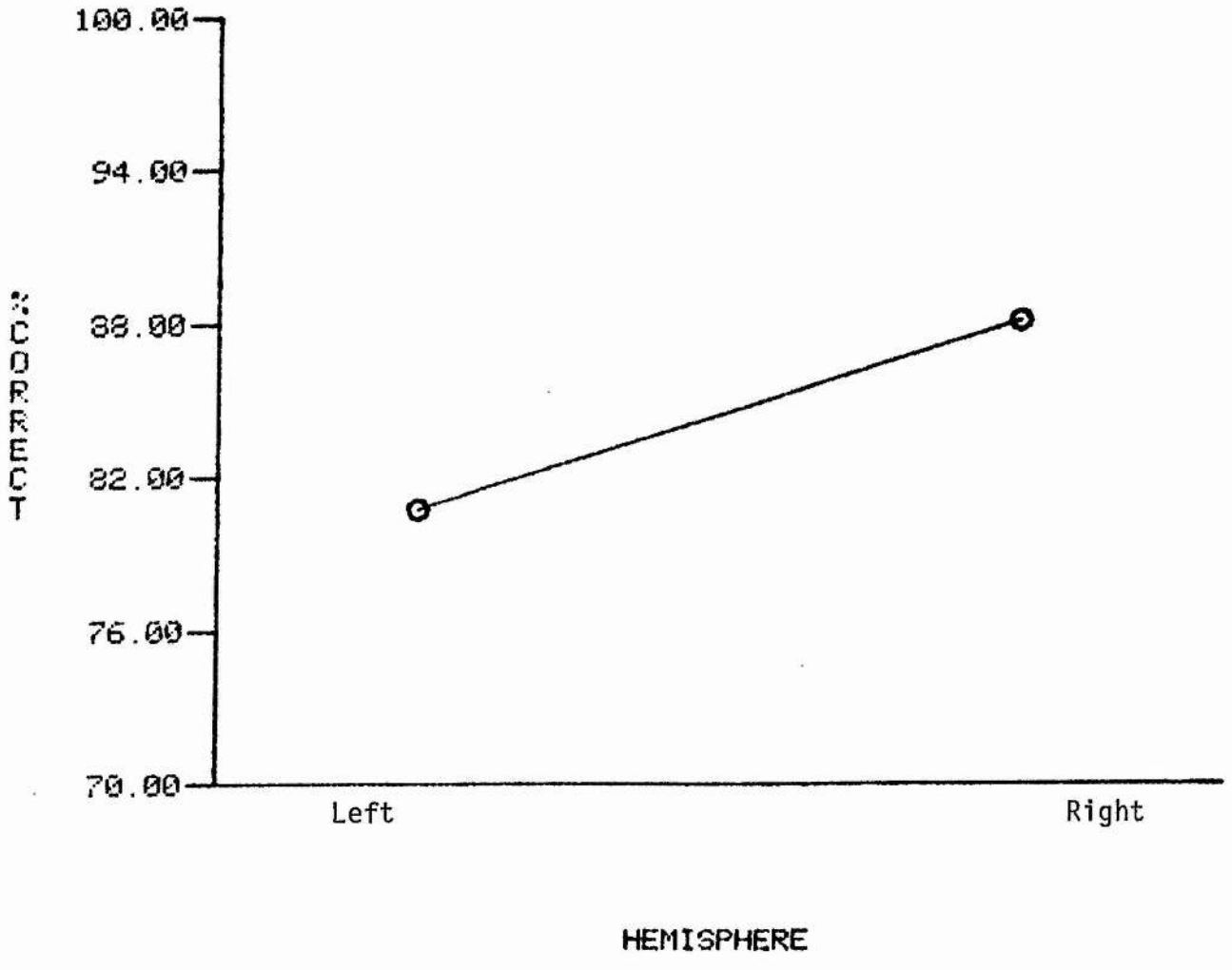


Figure 4.4

Experiment Two. Apparent motion of random dot stimuli. Hemispheric (ie contralateral VF) difference in percent correct scores.

hemisphere score was 80.78% (Figure 4.4). Eleven of the sixteen subjects (69%) gave overall right hemisphere percent correct scores superior to their left hemisphere scores.

There were no significant first or second order interactions.

The mean right handedness score as measured on the questionnaire, was for males 2.16, for females 2.16. The overall handedness mean was 2.16 with a standard deviation of .49.

Seven of the 16 subjects reported that their responses had not been mediated by sub-vocal verbalization, while six reported in the affirmative. Three subjects stated that their responses had "sometimes" been verbally mediated, for example, at the beginning of the experimental run, or when they were uncertain about the direction of motion and had to "think" about it. These three ambiguous cases were eliminated from the analysis, and the overall right hemisphere superiority scores (right hemisphere percent correct minus left hemisphere percent correct) of the two main groups were compared. Although the mean difference in right hemisphere superiority between the two groups was in the predicted direction: no sub-vocal verbalization group, mean R hemisphere - L hemisphere score = 11.79 , sub-vocal verbalization group, mean R hemisphere - L hemisphere score = 4.17 , $t = 1.12$ was not significant.

Discussion

The experiment examined the subject's ability to correctly respond to the direction of apparently moving low contrast visual stimuli. During the experiment, stimuli of equal contrast were presented in both visual fields. The contrast was set in pre-trials at close to each subject's threshold. The measure of hemispheric sensitivity was the number of correct responses (percent correct) made to stimuli lateralized to either the left or the right visual field.

As in experiment 1 (real motion), there was no statistically significant main effect for hand, nor for the hand x hemisphere interaction. We may here draw the same conclusions as previously. Similarly, there was no significant effect for sex, nor for the hemisphere x sex, hand x sex, or trials x sex interactions.

Also the triple interactions hemisphere x sex x trials and hemisphere x hand x sex were not significant.

Unlike experiment one, there was no significant change in performance over trials, and no significant hemisphere x trials interaction.

There was however an overall right hemisphere superiority, $p < .05$. The right hemisphere gave a mean percent correct score of 88.125%, while the left hemisphere scored 80.78%. Eleven of the 16 subjects (69%) recorded a superior right hemisphere score.

This significant right hemisphere advantage is in line with reported right hemisphere superiorities for certain visuo spatial tasks. (The appropriate literature is reviewed in Chapter one, and summarized in the Introduction to Chapter three.) And is specifically supportive of the motion perception work of Bertoloni et al. (1978) and Trevarthen and Sperry (1973).

In experiment one, it appeared that the verbal left (dominant) hemisphere might have interfered detrimentally with the right hemisphere's performance. In an attempt to examine this possibility, after completing experiment two, subjects were asked to report whether their manual responses had been mediated by sub-vocal verbalization. The prediction was that subjects so reporting would not show such strong right hemisphere effects as subjects who responded to the stimuli without sub-vocal verbalization. Seven of the 16 subjects reported no sub-vocal verbalization, while six did. (The three ambiguous cases were eliminated from this analysis.) Although the difference: Right hemisphere % correct - left hemisphere % correct, was in the predicted direction, $\overline{X}$ = 11.79 (no sub-vocal verbalization) vs. $\overline{X}$ = 4.17 (sub-vocal verbalization), the difference was nonsignificant (t = 1.12).

The significant hemisphere effect indicates that the right hemisphere is superior to the left when confronted with the task of responding correctly to the direction of apparent motion. In an analogous experiment involving

real motion (experiment one), a hemisphere x trials interaction, largely accounted for by the improvement of the right hemisphere, was observed. These two results lead to the conclusion of a right hemisphere processing superiority for the visual perception of movement.

However, further apparent motion experiments revealed left hemisphere superiorities for similar tasks which examined detection rates under different stimulus parameters. These results are reported in experiments three and four.

Thus, as a conclusion to experiment two, we may only say that the right hemisphere is superior to the left in an apparent motion task which involves the detection of the direction of motion of low contrast stimuli, when stimulus one and stimulus two are of relatively long duration and are separated by a short inter-stimulus interval.

CHAPTER 5

Experiment 3. A study of the apparent motion step from simultaneity to motion. Do the hemispheres differ in the ISI at which they begin to perceive apparent motion?

Introduction

In the previous experiment, we observed an overall right hemisphere superiority for the detection of apparent movement. Classical studies have examined the stimulus parameters which affect the perception of apparent motion (Exner, 1875; Wertheimer, 1912; Korte, 1915; Neuhaus, 1930).

As was discussed in the introduction to Chapter Four, if the brightness, spatial separation and temporal durations of the two experimental stimuli are kept constant, increasing the duration of the temporal interval between them (the inter stimulus interval, ISI) produces a range of percepts from simultaneity, through apparent movement to sequentiality.

It is commonly observed in apparent motion studies that there are measurable and consistent differences between individual observers in the ISIs at which they report these changes in the apparent motion percept. The current experiment was designed to examine whether the cerebral hemispheres display similar differences. The step examined in this study was the one between simultaneity

and motion. Specifically, we wished to determine whether one hemisphere began to see apparent motion at shorter ISIs than the other. A difference would indicate a greater sensitivity to the asynchrony of the stimuli. That is, the system detects that the two stimuli are not simultaneous, and this temporal disparity is interpreted as motion.

It will be recalled that in experiment two, good apparent motion could be perceived with an ISI of 1 ms. Therefore, in order to examine a range of ISIs, the increase in which would produce an improved percept of motion, it was necessary to conduct pilot studies to select a new set of stimulus parameters.

When such adjustments to the stimulus parameters are made, some additional perceptual phenomena characteristic of random dot stimuli are observed.

The data from the experiment proper indicate a left hemisphere superiority under the experimental conditions used.

Apparatus and Procedure I

The experiment was conducted in the same experimental room as experiment two, and employed the same three field tachistoscope (with the same neutral density gelatin filters in the stimulus fields), stimulus cards, response switch, electronic displays, headphones and warning tone, all described fully in the apparatus and procedure section of Experiment 2.

The background field of the tachistoscope (Fb) was again the fixation field, with field one (F1) and field two (F2) the stimulus fields. In this experiment, Inter-Stimulus Interval (ISI) was the independent measure (rather than contrast as in Experiment 2). The electronic unit of the tachistoscope was therefore programmed to switch off Fb during the presentations of F1 and F2 so as to produce stimuli of higher contrast not attenuated by a background of Fb.

Since the same stimulus cards as in Experiment 2 were employed, motion was again presented in only one direction (up or down) and in one visual field (left or right) on any individual stimulus presentation, although all combinations were presented during a block of experimental presentations.

Pilot Studies - Selection of Stimulus Parameters

The step in the classical apparent motion continuum of simultaneity to motion to sequentiality which was examined in this experiment was between simultaneity and

motion. Fairly extensive pilot studies were conducted using the random dot stimuli in the tachistoscope in order to select suitable stimulus parameters, i.e., stimulus durations, inter stimulus interval, and field brightnesses (with resultant contrast). These pilot studies were conducted initially by the experimenter, triggering the tachistoscope and observing a wide range of stimulus conditions. When a set of approximately suitable parameters had been chosen, these were tested on a number of assistants and from these studies the stimulus parameters used in the experiment proper were selected.

These studies indicated that for fixed stimulus field presentation durations and contrast levels, there was a range of ISIs between the limit where the correct direction of "motion" could not be detected (simultaneity) to where it could be correctly identified 100% of the time (motion). The experimental paradigm to be used was again the forced choice technique where the subject is obliged to respond to the direction of motion on each trial, and when uncertain, to guess. The number of correct responses was again to be used as the experimental measure. Therefore it was necessary to set the experimental parameters such that the subject made some errors, but responded at a level above chance (50%).

To examine whether one hemisphere preceded its counterpart by correctly identifying the direction of apparent motion at shorter ISIs, it was decided to present

four ISIs, which increased by constant amounts, to each subject. The shortest ISI being closest to stimulus conditions producing perceptions of simultaneity, the longest closest to perceptions of motion, with two equidistant values in between.

In an experiment such as this in which within a single subject, four ISIs, two hemispheres, and two hands are studied, it is necessary to have the subject view many stimulus presentations in order to produce statistically analyzable data. Therefore, minimizing the time between each presentation is an important practical consideration in experimental planning. Cognizance must be taken both of the overall experimental duration for which subjects may be reasonably be expected to participate before boredom or fatigue sets in; and the delay between each stimulus presentation which, if excessive, may result in the subject's attention wandering from the task in hand.

Inter trial dial changing on the tachistoscope could be minimized by choosing ISI step sizes of either 1 ms or 10 ms, i.e., min ISI +1, +2, +3 ms, or min ISI +10, +20, +30 ms, with the electronic unit set throughout on either ms, or ms x 10. Pilot studies revealed that 10 ms step were too gross, but a gradual change in percept between simultaneity and motion could be produced by increments of 1 ms.

In addition, it was found that setting Fb at 25 on the % Intensity Scale, and F1 and F2 at maximum, with the

gelatin neutral density filters (Experiment 2) still in place, produced stimuli of satisfactory contrast.

Stimulus field durations of 10 ms resulted in the required error response rates. Kolers (1964) and Neuhaus (1930) have also observed that for stimuli of long duration, motion may be observed at short ISIs; while short duration stimuli require longer ISIs for percepts of motion to be reported.

Significantly longer stimulus field durations were found to require lower brightness levels and a wider range of ISIs between the percept of simultaneity and motion.

During the experiment, the four ISIs set for each subject were designated a, b, c and d, with a the shortest, b = a+1 ms, c = a+2 ms, and d = a+3 ms.

Apparatus and Procedure - II

The .75 sec duration, 1 kh warning tone was presented through stereo headphones with equal intensity to each ear, 1 sec prior to each stimulus presentation.

During the experiment, Fb, containing the fixation field of a 1/8 in. diameter black spot centrally positioned on a white card, remained on except during the presentations of F1 and F2. The following sequence, with the field changes programmed on the electronic unit of the tachistoscope, constituted an experimental presentation. The subject receives the warning tone and fixates the central spot on Fb, 1 sec after the tone, Fb is switched off contemporaneously with F1 being switched on,

presenting the random dot stimulus card in F1 for 10 ms (stimulus 1, S1); F1 is switched off contemporaneously with Fb being switched on for the ISI (variable in duration and manually adjusted prior to each presentation); Fb is then switched off and F2 with its random dot stimulus card, on for 10 ms (stimulus 2, S2); F2 off, and Fb on again and remains on.
The subject responds.

The total stimulus duration is again well within the latency of eye movements.

An experimental presentation is represented in figure 5.1 (not drawn to scale).

The random dot stimulus cards (see Experiment 2) when viewed in pairs, produced a perception of a randomly textured square moving up or down across a random background either to the left or right of the fixation spot. The nearest edge of the moving square was 3^{o} visual angle (VA) from fixation, the furthest edge 6^{o} VA and the center of the square $4\text{-}1/2^{o}$ VA to the left or right of fixation. Therefore, with the subject focused binocularly on the fixation spot, the apparently moving small square was lateralized to either the left or right cerebral hemisphere.

As in Experiment 2, to control for any properties of the stimuli which might have favoured more accurate

detection of the direction of motion in one visual field, half the subjects viewed the cards in one orientation, while the other half of the subjects, matched for sex and the hand first used to respond, viewed the cards rotated through 180^{o}.

The experimental independent measure was the Inter-Stimulus Interval (ISI) which took four increasing values, set in pretrials around each subject's individual threshold. These ISIs were designated, a, b, c, and d, with a the shortest, b = a+1 ms, c = a+2 ms, and d = a+3 ms. For all subjects, the duration of both stimulus fields was 10 ms; the % Intensity scale (brightness) for Fb set at 25, and for F1 and F2 at maximum.

As in the previous experiments, subjects were asked to respond to upwards motion by moving the switch up; and to downwards motion by moving the switch down, irrespective of which side the motion occurred. The subject's response was again communicated electronically to a display from which the experimenter could read and record the subject's decision.

As in Experiments 1 and 2, subjects received no feedback as to the correctness of individual responses.

Stimulus Presentations and Response Sheets

Since in this experiment, four ISIs (a, b, c, and d) were presented to each subject (rather than one fixed low contrast level as in Experiment 2), it was necessary to

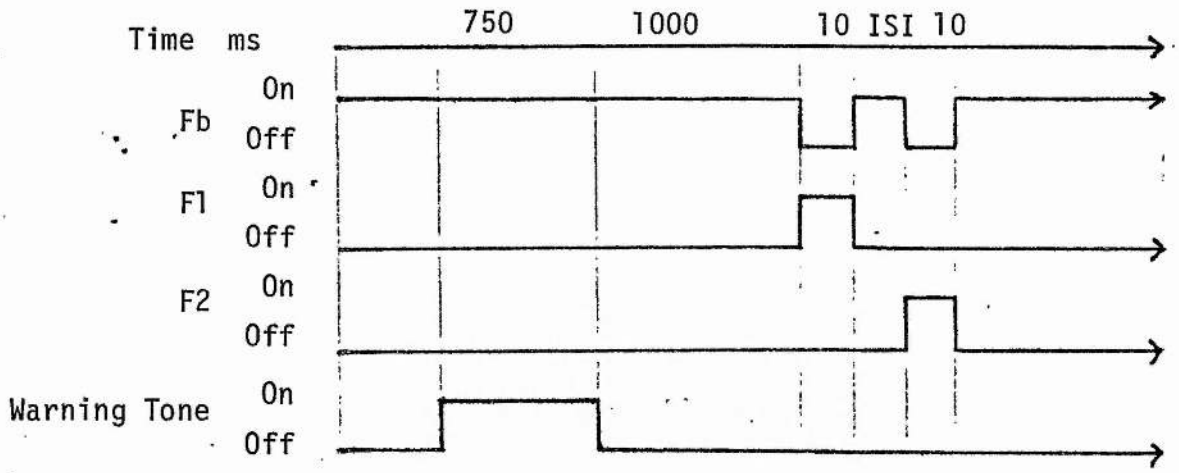


Figure 5.1

Experiment Three. Temporal sequence of events in an experimental presentation showing the on/off durations of the background field (Fb) and the stimulus fields (F1 and F2).

have the subject view more stimulus presentations in order to obtain analyzable data.

Also, with four ISIs, two directions of motion (up and down), and two visual fields (left and right), the smallest set of stimulus presentations which will contain one of each stimulus configuration, i.e., aUL, bDL .....cUR, dDR, is 16 (4 x 2 x 2), and sets of stimulus presentations containing equal numbers of each stimulus configuration must be multiples of 16.

As was noted in Experiments 1 and 2, subjects may comfortably complete around 40 such trials before requiring a break. Response sheets were therefore constructed listing 32 (16 x 2) stimulus configurations. These sheets on which the stimulus configurations were divided into two groups of 16, listed the configurations in a pseudo-random manner. The constraint being that each group of 16 contained one of each stimulus configuration, although these were ordered randomly.

To compensate for any effects produced by using sheets listing one particular random order, two sets of sheets were made up (sheets 6 and 7), one being the complete inverse of the other. Half the subjects, controlled for sex and hand used first, responded to the stimuli as ordered on sheet 6, while the other half, sheet 7. As in Experiments 1 and 2, individual subjects worked from the same sheet number, although none was aware of this. Thus for each subject, corresponding blocks of

trials from each sheet are directly comparable with respect to practice or fatigue effects.

It was considered that for the purposes of statistical comparison, a minimum of 20 stimulus presentations should be made at each ISI to each hemisphere. This results in a total of 160 (20 x 4 x 2) stimulus presentations, i.e., the use of 5 response sheets (32 x 5).

During the experiment, a randomly selected half of the subjects began responding with their left hand and the other half (controlled for sex) began responding with their right hand. After completing the initial 16 responses on the first sheet using one hand, subjects were given a short 2-3 minute break and then completed their responses to the stimuli listed on this sheet using their other hand. They were then given a break of similar duration. After the first sheet, subjects rested at the completion of each 32 stimulus presentation sheet, now responding to the whole of each sheet with the same hand. Thus:

Sheet	Stimulus Presentation Number	Hand Used
first	1-16	1
first	17-32	2
second	33-64	1
third	65-96	2
fourth	97-128	1
fifth	129-160	2

Subjects therefore responded to 80 balanced trials with each hand, and were given a short rest at each hand change. For the purpose of data analysis, presentations 1-32 were designated as trial one, 33-96 as trial two, and 97-160 as trial three.

Prior to running subjects, the experimenter wrote on the sheets, for each stimulus presentation, which stimulus cards would produce the appropriate stimulus display, e.g., during part 2 of the experiment, card 1 followed by card 4 produced motion down to the right cerebral hemisphere.

During the experiment, the data recorded were: the four threshold ISIs set for each subject; the responding hand; the contrast (constant); the response to each stimulus presentation; and whether the response was correct or wrong.

Since a forced choice technique was again used with the subject required to respond to each stimulus presentation, and obliged to guess if uncertain as to the direction of motion, it is possible to record 50% correct merely by guessing. Thus, an overall response rate of 97 correct out of 160, X^2 sig. < .01, is required to indicate that the subject is responding in a non-chance manner to the stimuli presented.

Visual Field Checks

As was reported more fully in the apparatus and procedure section of Experiment 2, field checks were

conducted priot to, during, and after running the experiment.

No visual field differences were observed in responses to foveally viewed stimuli.

Therefore, it may again be safely concluded that any visual field differences that the data reveal are a consequence of differential processing capacities within the observer, and not a function of disparities in the stimuli presented.

Apparent movement of the stimulus square in the "wrong" direction.

When the stimuli were first being constructed, it was observed that displacements of two (or more) items of texture resulted in ambiguous percepts of the direction of motion.

Note that the effects to be discussed in this section are observed for direct observation, as well as for lateralized presentations, so are not hemisphere effects.

Some subjects consistently reported motion in the "wrong" direction irrespective of the experimental parameters. Others only observed it with high contrast longer duration stimuli separated by longer ISIs. Motion was considered to be perceived in the "wrong" direction when the direction of motion observed was opposite to that in which the stimulus square was displaced. It should be

emphasized that these cases are different from the threshold presentations in which the subject is uncertain about the direction of motion but is obliged to guess.

The effects of varying ISI were studied with assistants who typically (for one dot displacements) saw motion in the "correct" direction. The displacements in this case were two items of texture 0.43^{o} VA and the stimuli were of high apparent contrast with Fb, the background field, switched off during the stimulus field presentations.

Specifically: S1 = S2 = 100 ms

F1 = F2 = 0.7 log ft lamberts

Fb = 0.25 log ft lamberts.

The effect is observed irrespective of the direction of displacement. Assume in the following discussion that the small square is displaced downwards in S2, so the correct report is "downwards motion."

For ISI = 1 ms, the motion appears downward. As the ISI is increased, the percept changes until at ISIs of around 20 ms, the square sometimes appears to jump briefly up then move more strongly down. In this case the subject may make his decision on the basis of the initial upwards movement so when responding quickly, may err. As the ISI is increased to over 40 ms, a random flicker is observed in the region of the displaced square with no clear associated motion.

With random dot stimuli, Braddick (1974) studied the effects of texture item displacement on the perceptability of rectangles in apparent motion. He found (using a dark ISI and texture items of varying sizes) the important variable to be the visual angle of the displacement, rather than the number of texture items through which the stimulus shape is displaced. Increasing the length of the ISI also made judgments of the orientation of the target stimulus more difficult.

In 1973, Braddick examined the effects of a bright or dark ISI on the perceptability of random dot squares in apparent motion. From his results, he suggested that a bright ISI acts as a masking stimulus, the effect of which increases with increasing ISI duration. This finding will be considered when the results of the current set of experiments are discussed.

For the one item of texture, 0.21^{o} VA, displacements used for the current experimental stimuli, observations of motion in the wrong direction were less frequent. However, for the conditions used in experiments 3 and 4, some subjects consistently reported motion in the wrong direction and others reported the ambiguous bi-directional jumpy motion. In both groups of subjects, there was no doubt that motion had occurred; the problem was that the perceived direction did not correspond to the square's displacement. Such subjects were screened out of the study during the pre experimental practice trials. Also

eliminated were the data from subjects whose total percent correct scores in the experiment did not differ significantly from chance indicating overall response inconsistency.

It should be recalled that subjects were volunteers and few were trained in psychophysical observation.

With one item displacements, the experimenter, like the majority of observers, was unable to see motion in totally the wrong direction. However, by adjusting the tachistoscope settings to produce the "worst" stimulus conditions, he could on some presentations observe the slight jump up then down motion described earlier. As in the two item displacement case, he found that such percepts were most likely when the background field Fb was switched off during the presentation of the random dot stimulus cards (rather than Fb remaining on during the entire stimulus sequence); and when S1 and S2 were longer, i.e., around 100 ms. ISIs of 10 ms or greater were also required. Other observers confirmed the increased likelihood of observing bi-directional motion for such stimulus adjustments. It should be noted that switching off Fb during stimulus presentations and increasing the duration of the stimuli both increase the apparent contrast.

The effect of motion briefly up then down (or conversely) was more apparent if one looked directly at the trailing edge of the moving square, with the "wrong"

direction of motion occurring at this locus. This, I think, is the result of the row of texture which was "under" the square in S1 being revealed in S2; thus it sometimes appears to move up while the square moves down. The experimenter always observed motion in the "correct" direction while looking directly at the leading edge which "covers" a row of texture in S2.

The preceeding observations were made during pilot studies prior to conducting the main experiments. They are included here to account for the elimination of subjects (see following section).

Subjects

The 16 subjects were 12 adult females (mean age 20.1 years, max 24 years, min 18 years) and four adult males (mean age 24.25 years, max 35 years, min 19 years). All were right handed (see results section) and all had normal or corrected vision. All the females were undergraduate students, two of the males were undergraduate students, one a postgraduate student, and one a research assistant, all at St. Andrews University.

Subjects had volunteered to participate in an experiment in visual perception. In Experiments 1 and 2, no sex differences had been observed. Therefore, when more females than males volunteered to participate, this did not appear to be a problem. However, within each sex group, subjects were balanced for hand used first, stimulus card orientation, and stimulus order sheets.

Three volunteers whose overall score was less than 97 correct out of 160, indicating chance performance, were excluded and replaced by other subjects.

Procedure with Subjects

Subjects were introduced to the experimental situation, informed about apparent motion, and appraised of their task in a fashion similar to that reported fully in the corresponding section of Experiment 2. Therefore, only aspects of the two procedures which differ are detailed here.

As the majority of the subjects in this experiment were female, we use the pronoun she.

In the pre trials, the stimulus field durations and contrasts were set as for the experiment proper. However, the ISIs were of a somewhat longer duration, set for each subject so that she could clearly see apparent motion in the correct direction.

When the subject had become familiar with the stimuli and the experimental task, the ISIs for the experiment proper were set for each individual with the subject wearing the headphones (receiving the warning tone), fixating the spot binocularly and responding to the stimuli via the response switch. The ISI for each of these random stimulus field presentations was reduced for each succeeding presentation until the subject made an error, or hesitated noticeably before responding. Further presentations were now made with ISIs slightly above and

below this approximate threshold to more accurately determine the subject's limen. On the basis of these presentations, four ISIs separated by 1 ms were chosen as ISIs for the experiment proper. Further trial presentations using these ISIs verified that they were in the correct range, i.e., response rate to the shortest was above 50% correct, and to the longest below 100%.

When the experimenter was satisfied that the ISIs chosen were in the correct range and the subject was familiar with the task, these trials were ended. The subject was informed that stimulus presentations would be made at four different ISIs, so she should not be surprised if some trials appeared less distinct than others.

The subject was told that she would be given breaks between blocks of trials, and would switch responding hand for the succeeding block. The experimenter would keep track of which hand should be used.

The subject was then given a resume of the experimental instructions, i.e., moving the switch up for upwards motion, down for downwards motion, irrespective of the visual field where motion occurred; the hand to use first; the necessity of responding as quickly as possible and when in doubt guessing; and the importance of fixating the central spot during stimulus presentations.

The experiment proper was then begun.

At the completion of the experiment, the subject filled out the handedness questionnaire and was asked whether her responses had been mediated by sub vocal verbalization. The purpose etc. of the experiment was now fully explained.

The subject was then thanked for participation and asked to recruit friends as subjects but not to discuss the hemispheric nature of the study with them prior to their participation.

Luminance Levels of Stimulus Fields

For all subjects, the % Intensity scales for F1 and F2 were set at maximum (with the neutral density gelatin filters still in place), and Fb set at 25. Note that in this experiment, Fb is not switched on contemporaneously with the stimulus fields.

The luminances of the fields were measured with the fields switched on continuously using the SEI photometer, with the textured stimulus field measurements taken at white items of texture.

The values presented are the means of a number of photometer readings taken at different points on the stimulus fields. There were no differences in the values obtained at different points in a stimulus field; or for the different stimulus cards.

Values

Field	% Intensity Setting	Luminance log.ft.lamberts
Fb	25	0.8
F1 or F2	max	0.7

Results: Experiment Three

The mean minimum ISI, a, set by subjects was 6.625 ms, min 2 ms, max 8 ms, SD, 1.89. It will be recalled that for the other ISIs, b = a+1 ms, c = a+2 ms, and d = a+3 ms.

Percent Correct (All Subjects)

Trial 1	66.21
Trial 2	75.78
Trial 3	73.14

Table 5.1

Percent Correct (All Subjects)

ISI a	68.36
ISI b	68.49
ISI c	71.48
ISI d	78.52

Table 5.2

			Male		Female	
Hand	Hem.	ISI	Mean	SD	Mean	SD
L	L	a	50.00	40.82	62.50	31.08
L	L	b	50.00	40.82	62.50	31.08
L	L	c	87.50	25.00	58.33	46.87
L	L	d	87.50	25.00	75.00	33.71
L	R	a	50.00	40.82	62.50	31.08
L	R	b	87.50	25.00	54.17	25.75
L	R	c	62.50	47.87	50.00	30.15
L	R	d	100.00	00.00	62.50	43.30
R	L	a	62.50	47.87	75.00	33.71
R	L	b	62.50	25.00	70.83	33.43
R	L	c	62.50	47.87	70.83	25.75
R	L	d	87.50	25.00	83.33	24.62
R	R	a	75.00	28.87	54.17	39.65
R	R	b	62.50	25.00	58.33	35.89
R	R	c	75.00	28.87	66.67	32.57
R	R	d	75.00	28.87	66.67	32.57

Table 5.A.

Experiment Three. Summary data. Percent correct Trial One across all subjects. Males (n = 4) and Females (n = 12). ISIs increase in 1ms steps.

			Male		Female	
Hand	Hem.	ISI	Mean	SD	Mean	SD
L	L	a	75.00	28.87	81.25	18.44
L	L	b	81.25	12.50	75.00	30.15
L	L	c	93.75	12.50	75.00	28.20
L	L	d	93.75	12.50	77.08	22.51
L	R	a	81.25	23.94	68.75	15.54
L	R	b	87.50	14.43	64.58	22.51
L	R	c	100.00	00.00	66.67	16.28
L	R	d	87.50	25.00	72.92	24.91
R	L	a	87.50	14.43	75.00	23.84
R	L	b	87.50	25.00	81.25	21.65
R	L	c	87.50	14.43	83.33	19.46
R	L	d	87.50	14.43	91.67	16.28
R	R	a	68.75	31.46	66.67	22.19
R	R	b	68.75	23.94	54.17	29.84
R	R	c	87.50	14.43	62.50	25.00
R	R	d	87.50	14.43	66.67	24.62

Table 5.B.

Experiment Three. Summary data. Percent correct Trial Two across all subjects. Males (n = 4) and Females (n = 12). ISIs increase in 1ms steps.

			Male		Female	
Hand	Hem.	ISI	Mean	SD	Mean	SD
L	L	a	62.50	25.00	68.75	21.65
L	L	b	75.00	00.00	68.75	32.20
L	L	c	93.75	12.50	69.17	20.87
L	L	d	100.00	00.00	81.25	24.13
L	R	a	87.50	14.43	66.67	30.77
L	R	b	56.25	31.46	70.83	20.87
L	R	c	87.50	14.43	60.42	27.09
L	R	d	93.75	12.50	66.67	24.62
R	L	a	62.50	25.00	66.67	30.77
R	L	b	87.50	14.43	66.67	32.57
R	L	c	81.25	23.94	79.17	17.94
R	L	d	93.75	12.50	85.42	19.82
R	R	a	75.00	28.87	66.67	19.46
R	R	b	81.25	23.94	72.92	19.82
R	R	c	68.75	23.94	62.50	22.61
R	R	d	81.25	23.94	68.75	26.38

Table 5.C.

Experiment Three. Summary data. Percent correct Trial Three across all subjects. Males (n = 4) and Females (n = 12). ISIs increase in 1ms steps.

Percent Correct

	Male	Female
ISI a	69.79	67.88
ISI b	73.96	66.67
ISI c	82.29	67.88
ISI d	89.58	74.83

Table 5.3

Percent Correct (Female)

Trial 1	64.58
Trial 2	72.66
Trial 3	70.70

Table 5.4

Percent Correct

	Left Hemisphere	Right Hemisphere
All subjects (n = 16)	75.85	67.58
Females (n = 12)	74.74	63.88

Table 5.5

Percent correct scores were calculated for each hand/hemisphere/trial/condition for all subjects.

Analyses of variance were performed on these data to test for statistically significant effects. The within subject variables were hemisphere (left and right); hand

(left and right); trial (one, two and three); and condition (four increasing inter stimulus intervals). The between subject variable was sex (male and female). However, since the 16 volunteer subjects were 12 females and 4 males, and these two populations did not appear to produce similar data, three analyses of variance were performed.

In this experiment, since subjects use both left and right hands during each trial, hand x trial effects may now be examined.

In the first analysis of variance performed, due to the unequal numbers of male and female subjects, sex was not entered as a factor. The overall mean percent correct response rate was 71.71%.

The significant main effects were trial, $p < .001$, Table 5.1, figure 5.2, subjects improving between trials one and two and dropping only slightly during trial three; ISI, $p < .001$, table 5.2, figure 5.3, subjects scoring equally on ISI a and b and improving thereafter (as ISI increases). Hemisphere came close to significance, $p = .054$, the left hemisphere scored 75.85% correct while the right hemisphere scored 67.58%, table 5.5, figure 5.4. Hand was nonsignificant (left 85%, right 83.9%). There were no significant first or second order interaction effects. (Hemisphere x ISI, p=.320, table 5.6).

Percent Correct (All Subjects)

	Left Hemisphere	Right Hemisphere
ISI a	70.31	66.41
ISI b	71.61	65.36
ISI c	76.82	66.15
ISI d	84.64	72.39

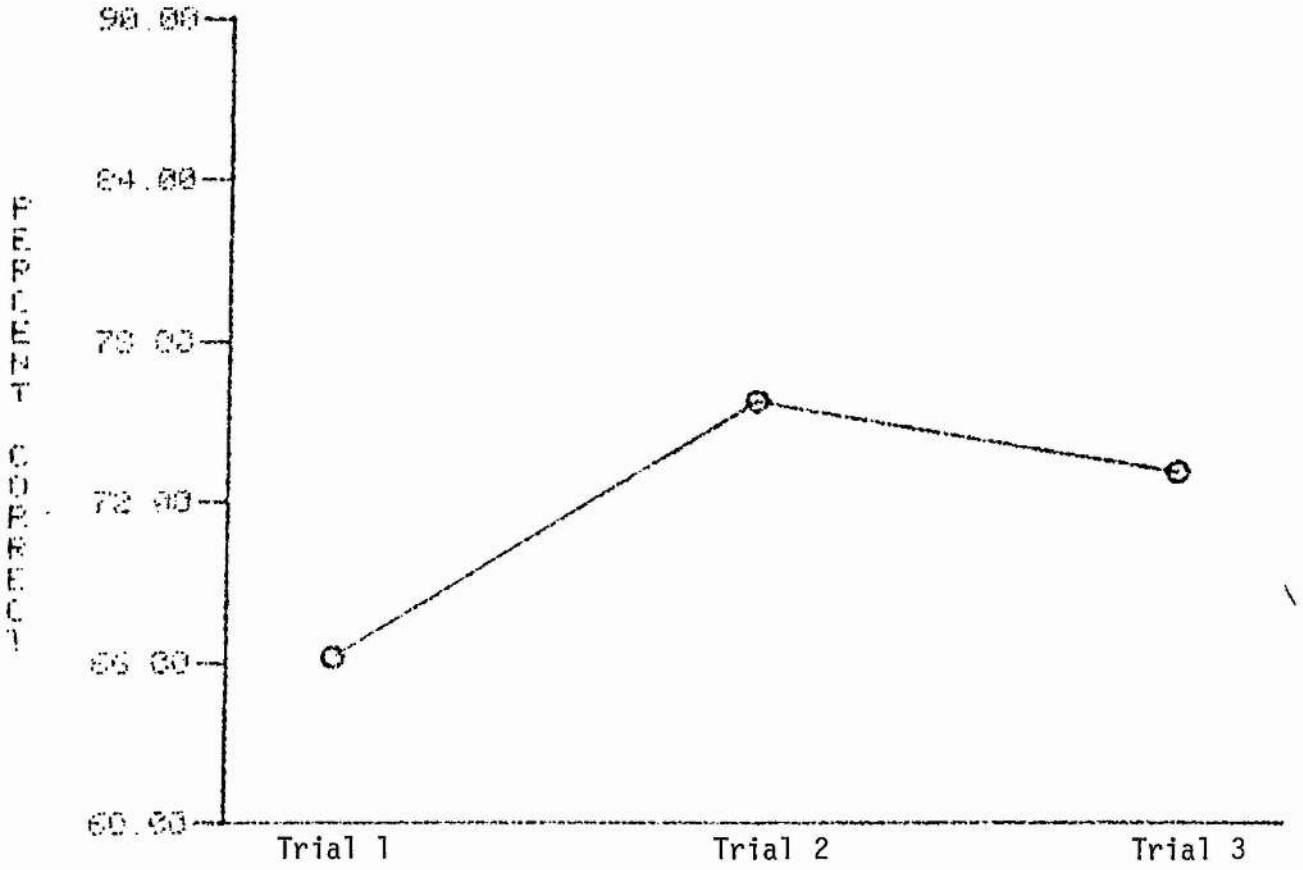
Percent Correct (female)

	Left Hemisphere	Right Hemisphere
ISI a	71.53	64.24
ISI b	70.83	62.50
ISI c	74.31	61.46
ISI d	82.29	67.36

Table 5.6

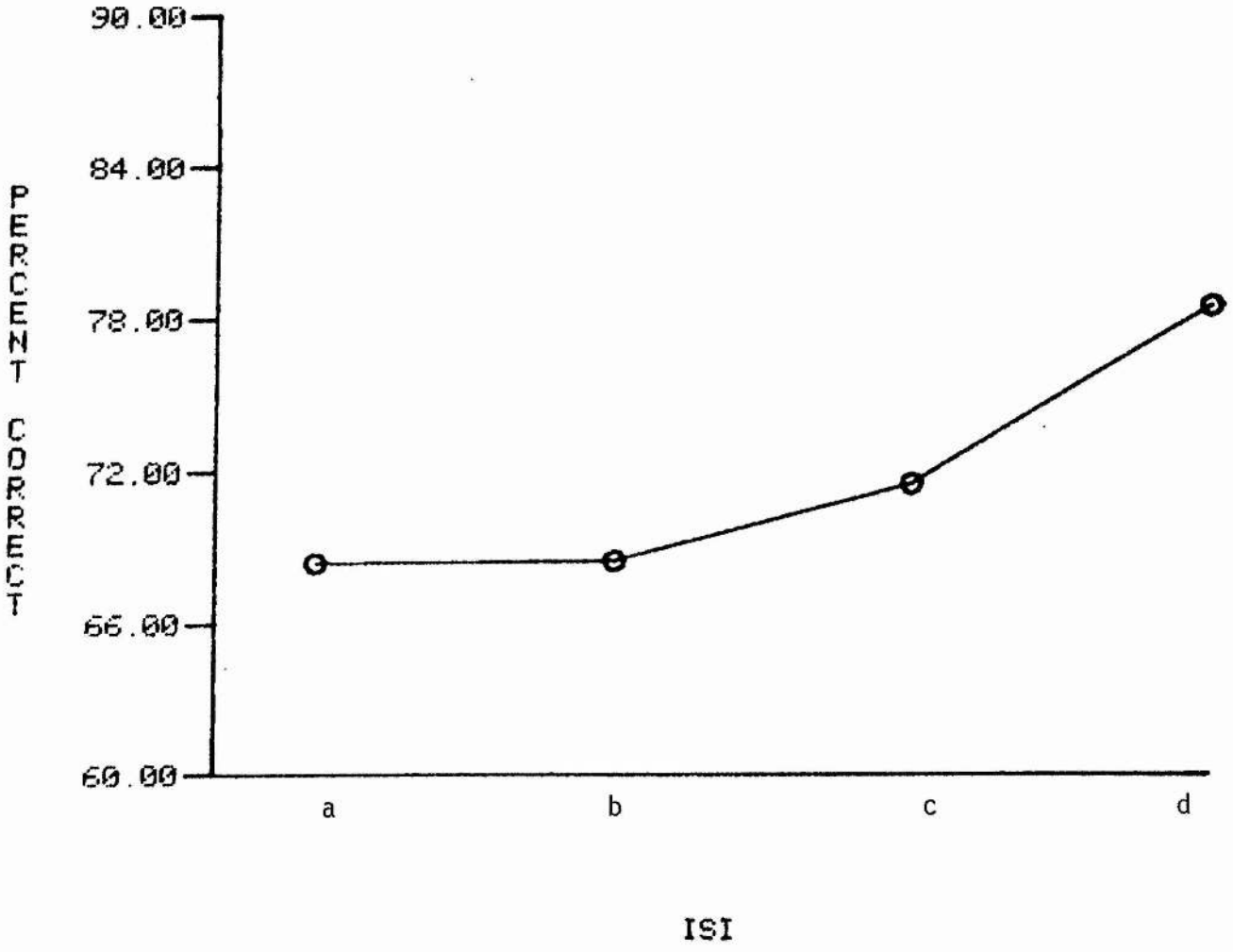
Although ISIs were set individually for each subject, the mean ISIs for the male and female groups did not differ significantly, $t=1.789$, $df=14$. It therefore appears legitimate to compare these groups. The mean minimum ISI for males was 5.25ms, for females 7.08ms.

FIGURE 5.2



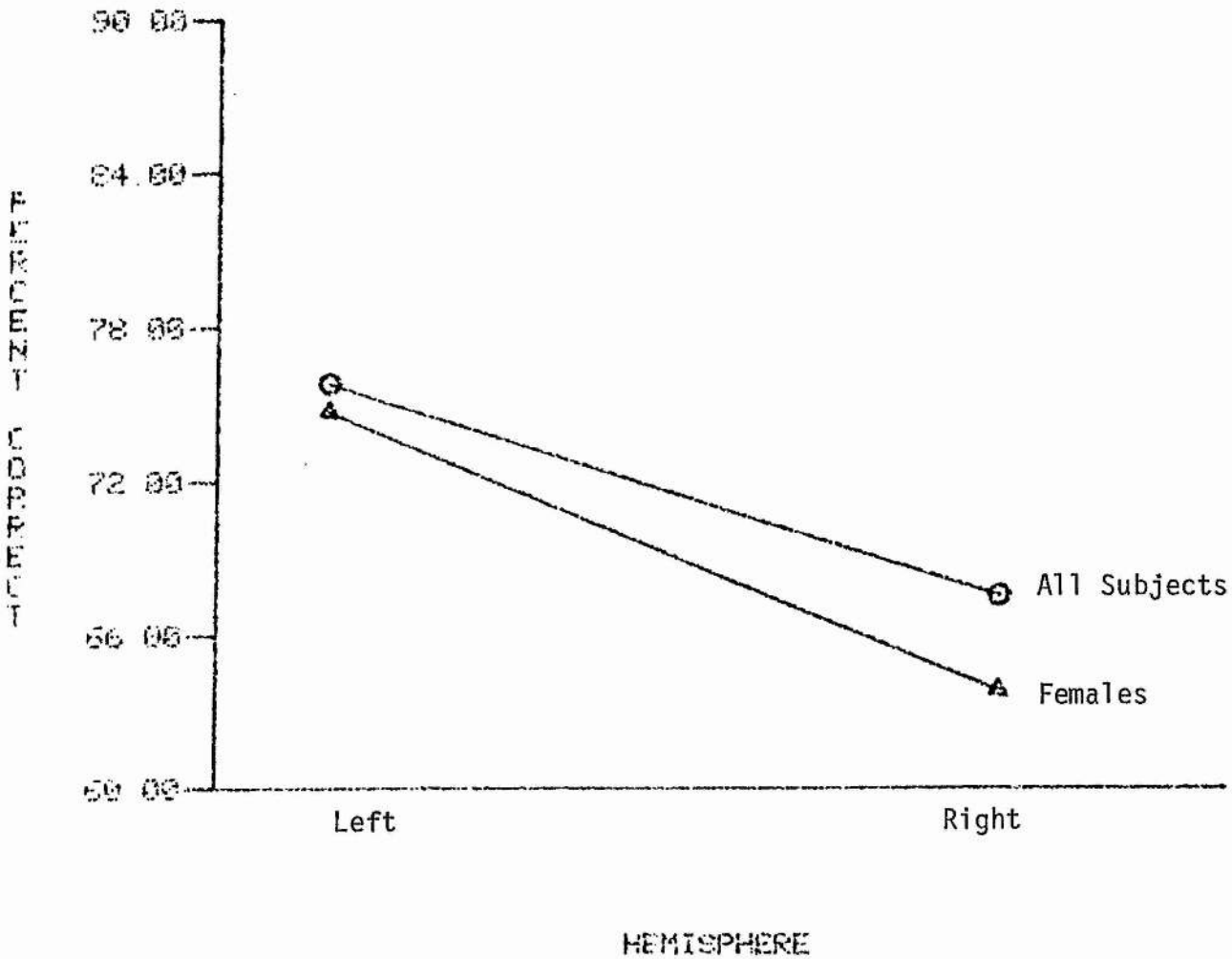
Experiment Three. Change in percent correct over trials. All subjects.

FIGURE 5.3



Experiment Three. Increase in percent correct with increasing ISI duration. All subjects.

FIGURE 5.4



Experiment Three. Left and Right hemisphere (ie contralateral VF). Percent correct scores plotted for all subjects (n = 16) and Females (n = 12).

The next analysis included sex as a variable. Trials and ISI were again significant (as above). Sex was significant at $p < .05$, males scored 78.91% correct, while females scored 69.31%. However, now hemisphere was nowhere near significance, $\underline{p} = .23$. The only significant interaction was ISI x sex, $\underline{p} < .02$, Table 5.3, Figure 5.5, males improved linearly with increasing ISI, while females improved only for the longest ISI. There were no significant higher order interactions.

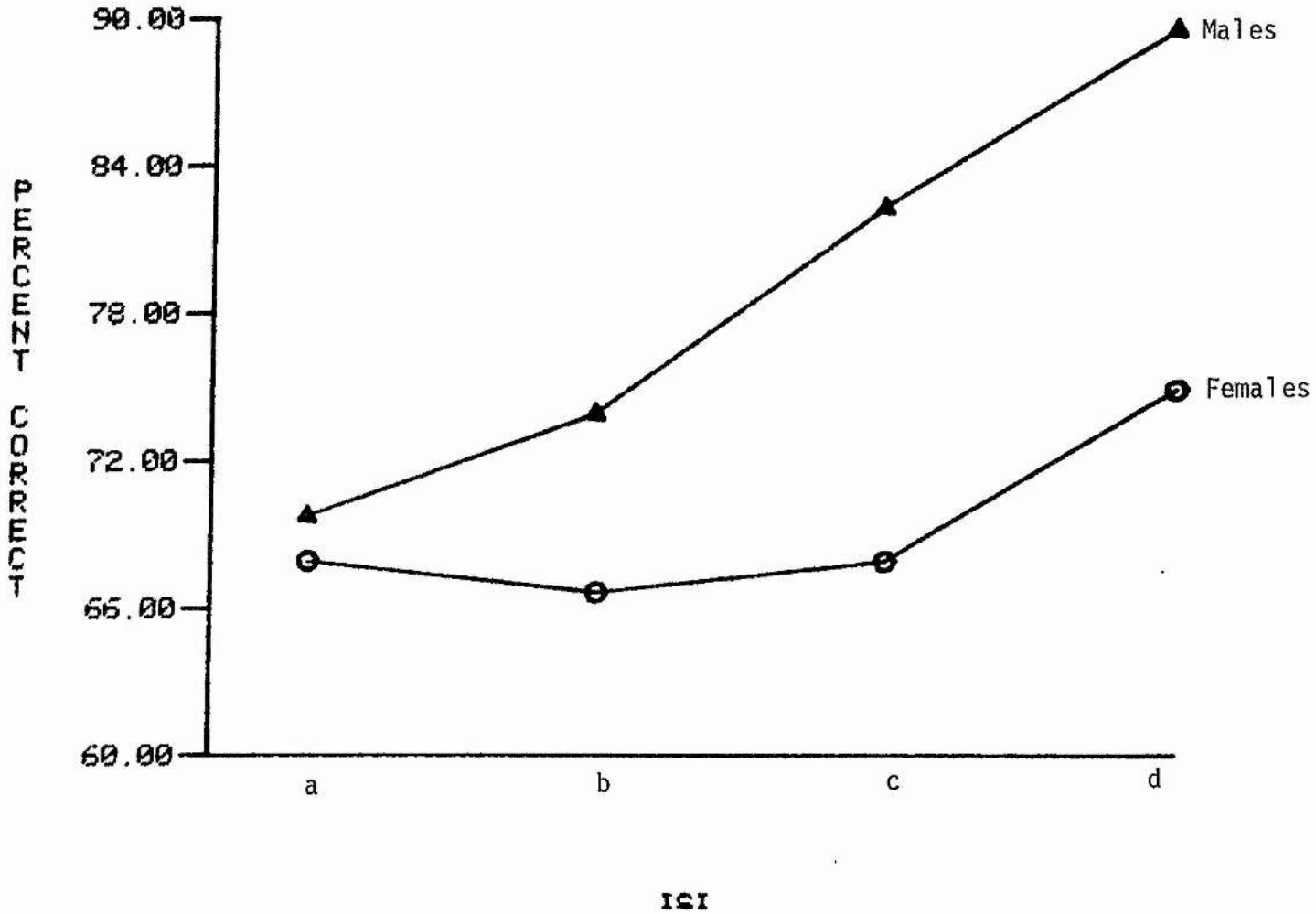
From these two analyses, it appears that the nearly significant left hemisphere superiority in the pooled data occurs as a result of the female experimental population. This is slightly surprising, since the raw data of the males show two subjects to be left hemisphere dominant, one no difference and the other right hemisphere dominant.

The small number of males, the variance of their data, and the weighting process of the analysis of variance must explain the obliteration of the hemisphere effect in the second analysis.

To check for possible hemisphere effects in the females, an analysis of variance was performed for these 12 subjects, nine of whom showed a left hemisphere superiority.

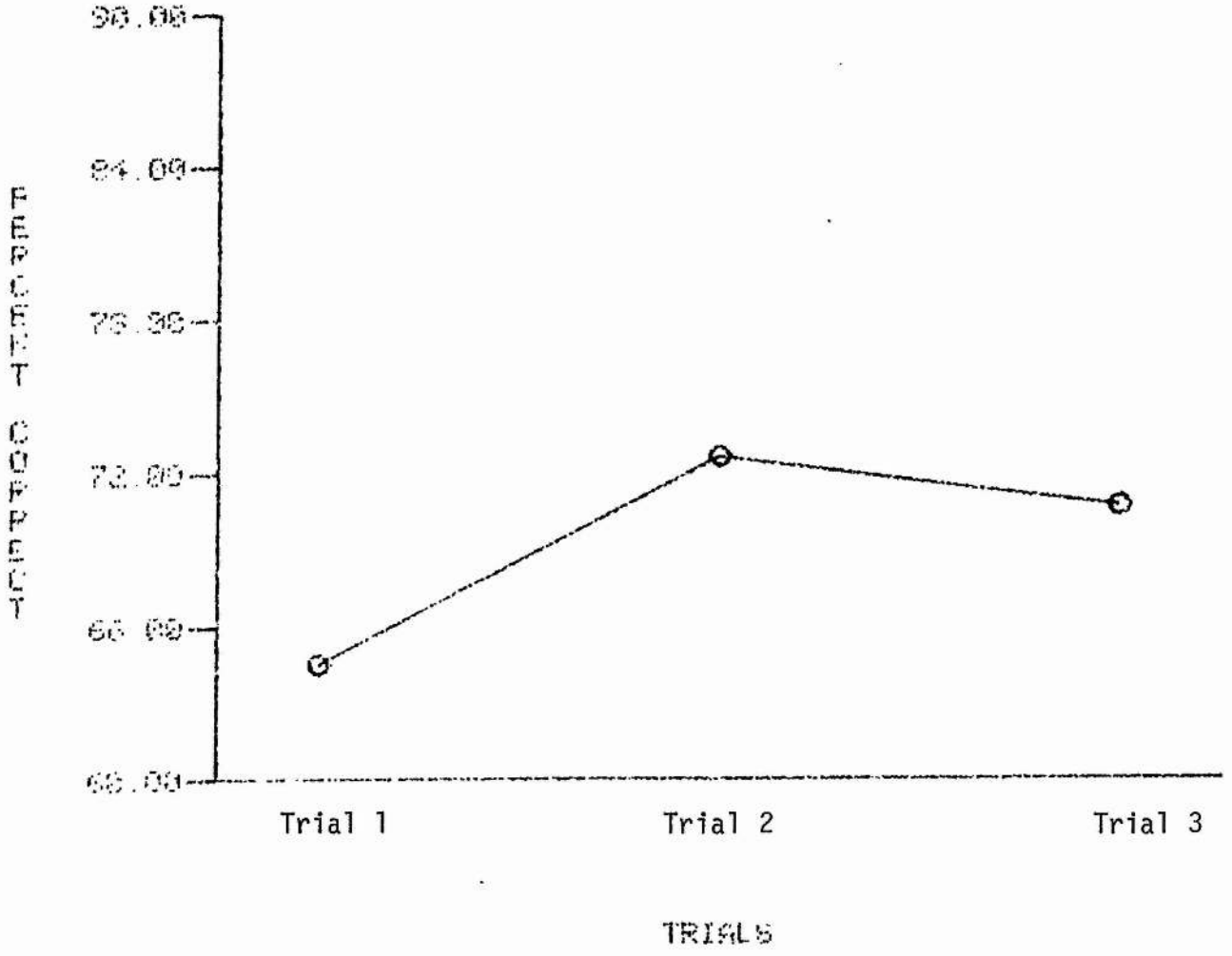
Trial was significant, $\underline{p} < .02$, table 5.4, figure 5.6, the improvement after trial one to an asymptote is again observed, cf. fig. 5.2. ISI was significant, $\underline{p} < .01$, with improvement in percent correct occurring for the

FIGURE 5.5



Experiment Three. Percent correct scores as a function of increasing ISI. Difference between Male (n = 4) and Female (n = 12) subjects.

FIGURE 5.6



Experiment Three. Change in percent correct over trials, Female data.

longest ISI (see table 5.3, figure 5.5, female data). Hemisphere was significant at $p < .025$, with the left hemisphere superior 74.74% correct, and the right hemisphere 63.88% correct, figure 5.4, table 5.5. Hand was nonsignificant, as were none of the double or triple interactions. (Hemisphere x ISI p=.406).

The mean right handedness score for males was 2.60, standard deviation = .18, for females 2.32, standard deviation = .30, for all subjects mean = 2.39, standard deviation = .30.

The four males, and five of the females reported that their responses had not been mediated by sub-vocal verbalization. Five females reported that they had used sub-vocal verbalization while the remaining two only did so when uncertain of the direction of motion. The latter two subjects were eliminated from the statistical comparisons. Each subject's right hemisphere score was subtracted from the left hemisphere score, and t tests performed on the resultant differences which compared the "yes" sub-vocal verbalization group with (1) all "no" subjects, (2) the female "no" subjects. There were no statistically significant differences between the groups.

Discussion

The experiment sought to examine whether there were hemispheric differences for the inter stimulus interval at which apparent motion was first perceived. Four

increasing ISIs were examined at the onset threshold of apparent motion for 16 subjects. The stimuli were random dot patterns in which a lateralized square figure was displaced either up or down. The subject's task was to correctly detect the direction of motion and manually respond.

There were no hand; hand x hemisphere; hand x trials; hand x ISI; or hand x sex effects. The hand used to respond has therefore no influence on the percent correct; there is no hemisphere to hand pathway effect; one hand does not selectively worsen or improve over trials; responding hand does not interact with ISI; and the sexes perform equally well with both hands.

Trials was significant, $p < .001$, figure 5.2 Subjects improved after trial one, 66% correct, to respond at around 75% correct for trials two and three. This indicates a practice effect. The improved performance shown in trial two is presumably due to subjects becoming more skilled in discriminations during trial one, while the 2.6% drop for trial three may indicate a very slight fatigue effect.

Trials did not interact with any of the other variables indicating that the improvement was not a function of any of the other parameters examined.

The significant ISI effect, $p < .001$, table 5.2, figure 5.3, shows no improvement in the detection of the direction of motion as ISI a is increased by 1 ms to ISI

b, and a slight increase for ISI c. Detection rates improve dramatically for ISI d. These data indicate that overall the study was examining ISIs in the region where motion becomes clear. And that when this ISI is reached, small increments significantly improve the detectability of the direction of motion.

ISI and hemisphere did not interact. There appears to be no difference between the performance of the hemispheres which is a function of ISI over this range.

In the previous experiments, there were no significant main sex effects or interactions. So when more females than males volunteered to participate in the experiment, this did not seem to constitute a problem (4 males and 12 females).

However, when a further analysis of variance which included sex was performed, it was found that the male subjects significantly ($p < .05$) outscored the females (78.9 vs 69.3 percent correct). The only significant interaction in this analysis was sex x ISI ($p < .02$), figure 5.5. The males improved linearly for increasing ISI while the females only improved for the longest ISI. This would tend to indicate that the males start to perceive the correct direction of motion at shorter ISIs than females. The males appear to have reached the threshold at which detectability substantially improves at ISI b, while the females do so at ISI d. The resultant differences in percent correct at ISI a, b, and d give the

overall male superiority. This male advantage is in line with the male superiorities for numerous visuo spatial tasks reviewed by Harris (1978). However, since there were only four male subjects and the variance of their data was fairly high, we may have sampled an anomalous subset of the male right handed population. Experiment 4, with even numbers of male and female subjects, will further examine the possibility of a male superiority for the detection of apparent motion under similar stimulus conditions.

In the first analysis, which did not include sex as a variable, the hemisphere effect came close to significance, $p = .054$. The left hemisphere scored 75.85% correct, the right 67.58%. No higher order hemisphere effects were observed. In the second analysis, which included sex as a variable, hemisphere was not significant. It appeared that the small number of male subjects, the weights applied to the males' data by the analysis of variance program and the high variance of their data resulted in a suppression of the hemisphere effect. This occurred although only one of the four males was right hemisphere superior. The suggestion that the males might be an anomalous group led to the analysis of the data from the 12 female subjects.

For these subjects, trial was again significant ($p < .02$), the pattern was similar to that of the whole population (figure 5.6) although the scores were slightly

reduced (Table 5.4). ISI was also significant, $p < .01$, Figure 5.5 female data, and has been discussed earlier. Now, however, hemisphere was significant at $p < .025$, Figure 5.4, Table 5.5. The left hemisphere scored 74.74% correct, the right 63.88%.

t-tests of the data from all observers, and from the females, showed that whether a subject reported using sub-vocal verbalization or not was not significantly related to hemispheric dominance.

The left hemisphere advantage observed in this experiment appears to be in conflict with the result of Experiment 2 in which a right hemisphere superiority was found.

The original purpose of conducting Experiment 3 was to examine whether one hemisphere preceded the other in correctly detecting the direction of the apparently moving stimulus square. This question seems to have been resolved in the negative. The highly significant ISI effect shows that over the range of ISIs studied, a dramatic increase in percent correct is observed. However, there is no hemisphere x ISI interaction indicating that a comparable increase in correct response rate takes place for both hemispheres as ISI increases. (The ISI x sex curves well illustrate the type of interaction which would be expected if the ISI x hemisphere hypothesis had been confirmed.)

The left hemisphere superiority appears therefore to be present over the whole ISI range examined. Since the left hemisphere superiority was significant only for the female subjects, it may be that this hemisphere effect is sex linked.

Kimura (1969) found male, but not female, right hemisphere superiorities for some of her dot localization tasks, as did McGlone and Davidson (1973) for dot enumeration. Davidoff (1977) observed a right hemisphere superiority for males for a low contrast dot detection task but no difference for females. While for verbal dichotic listening tasks, Lake and Bryden (1976) report a higher proportion of males showing right ear (left hemisphere) superiorities. These data suggest that females tend to be less lateralized than males with respect to both visuo spatial and verbal tasks.

Given these reports, and a lack of sex differences in experiments 1 and 2, we are inclined to think that the currently observed left hemisphere advantage is statistically significant only for the female subjects because a very small sample of males were studied, and we have not made a general finding. However, we shall further examine sex x hemisphere effects in Experiment 4.

A more general account of the left hemispheric advantage is that in the current experiment the bright ISI is acting as a masking field, producing an effect similar

to that reported by Braddick (1973) for random dot apparent motion stimuli.

In Experiment 2 (Chapter 4) the stimulus fields were superimposed on the fixation/background field (figure 4.3). Consequently, there were no abrupt changes in overall stimulus intensity as the fields changed. (In addition, the ISI was one ms.) In the current experiment, the fixation field is switched off during the presentation of the stimulus (random dot) fields (figure 5.1) and on again for the ISI. In this situation there is no constant background field but an abrupt change from the first stimulus field to a bright field during the ISI. The latter conditions Braddick (1973) found gave rise to a masking effect which abolished the apparent motion observed for an equivalent dark ISI.

Oscar-Berman et al (1973) using word and shape stimuli; McKeever and Suberi (1974), letters; and Cohen (1976), letters; showed that the right hemisphere was more susceptible to visual masking effects than the left. The right hemisphere apparently requiring longer to consolidate, code or process the visual trace.

In the current experiment, we appear to be observing similar effects for random dot stimuli, with the right hemisphere more affected by the "masking" ISI in Experiment 3. Note, too, that in Experiment 2, S1 was 500 ms in duration which would give a stimulus onset

asynchrony of a duration greater than that likely to result in masking.

Two questions have been raised by Experiment 3:

1. Does the left hemisphere superiority hold only for female subjects?

2. Is the left hemisphere advantage observed only under conditions in which the ISI is acting as a masking stimulus?

These questions will be examined in Experiment 4.

CHAPTER 6

Experiment four. Differences in hemispheric susceptibility to a masking inter stimulus interval. A further apparent motion study using random dot stimuli.

Introduction

In the previous experiment we observed a left hemisphere superiority for the detection of the direction of apparent motion. This result was explained in terms of a masking ISI which it was postulated affects the right hemisphere more than the left.

To further clarify this possibility, it was decided to set up an experiment in which various stimulus conditions could be examined simultaneously. These would involve an ISI expected to produce masking and an ISI expected not to. Also the "masking" ISI would take values which should produce stronger masking effects. These "masking" ISIs would be compared to the "non-masking" ISIs which would take equal values.

Random dot stimuli would again be used which would be presented so as to produce percepts of apparent motion which would be selectively available to either the left or right cerebral hemisphere.

It is predicted that for conditions in which a masking ISI is presented, the left hemisphere will outscore the right. Whereas for non-masking ISIs, there

will be no difference or a right hemisphere advantage will be observed.

In the previous experiment, there was an indication that such lateralization effects might occur only for female subjects. This possibility will be examined by running equal numbers of each sex as subjects.

Apparatus and Procedure

The experiment was conducted in the same experimental room with ambient light levels as in Experiment 2, and used the same three field tachistoscope with the neutral density filters inserted in the stimulus fields. The same stimulus cards, response switch, electronic response displays, headphones and warning tone were also used. These are all fully described in the corresponding section of Experiment 2.

With the same stimulus cards, motion is presented on a particular trial in either the left or right stimulus field, and motion is either up or down. During the experiment, all combinations are presented. The moving squares are sufficiently displaced from the centre of the field to ensure hemispheric lateralization provided the subject is fixating the central spot during a stimulus presentation. See Experiment 2.

To make this experiment comparable to the previous ones, a forced choice procedure was again used. The same intra subject variables were examined, i.e., hemisphere, hand and trials. It was found in Experiment 3 that, with appropriate breaks, subjects could view a sufficient number of stimulus presentations to produce statistically analyzable data when four ISIs were used. However, it was felt that requiring subjects to make more than 160 observations in an experimental session would be excessive. Consequently, it was decided to structure

Experiment 4 on the design used in Experiment 3, and select four different ISI conditions.

In Experiment 2, the fixation/background field, Fb, remained on throughout the stimulus presentation, with the random dot stimulus fields superimposed on Fb. There were no large changes in overall intensity during the stimulus display. Under such conditions, the ISI did not appear to be acting as a mask. Conversely, in Experiment 3, with Fb being switched off during the presentation of the random fields and on again for the ISI, a masking effect did appear to occur.

Braddick (1973) found that by increasing the duration of a bright ISI, the percept of apparent motion could be abolished.

It was therefore decided to study four stimulus presentation conditions defined as follows:

1. Fb is switched off during the presentation of the random dot stimulus fields and on for the ISI. The ISI is short.
2. Fb is switched as for condition 1. The ISI is longer.
3. Fb remains on throughout the entire stimulus presentation. The ISI is equal to the ISI in condition 1.
4. Fb remains on as in condition 3. The ISI is equal to the ISI of condition 2.

(In conditions 3 and 4, Fb is continuous, while in conditions 1 and 2 it is interrupted when the random dot stimulus fields are presented.)

It will be seen that if our expectations concerning the masking effect of the ISI are correct, conditions 1 and 2 should produce masking with greater masking occurring for condition 2, due to the longer ISI. The ISI in conditions 3 and 4 should not produce masking, though again we can compare the effects of increasing the ISI.

The effects of a masking vs. a temporally equal non-masking ISI may be examined by comparing condition 1 with condition 3, and condition 2 with condition 4.

It was necessary to conduct pilot studies to select stimulus parameters which would satisfy the four conditions described above, but which could be viewed by a subject within the same block of experimental presentations without appearing too different phenomenally.

Pilot Studies - Selection of Stimulus Parameters

These studies were initially conducted by the experimenter triggering the tachistoscope and viewing the stimuli. When a set of stimulus parameters had thus been approximately selected they were checked by the observations of a number of assistants.

In order to keep inter stimulus presentation time to a minimum (see discussion of this point in the pilot studies section of Experiment 3), it was decided to use ISI = 1 ms and ISI = 10 ms, thus eliminating much dial

turning on the tachistoscope. It was now necessary to select stimulus field durations and brightnesses which would give approximately similar percepts for conditions 1, 2, 3 and 4.

In the following discussion, the durations of the random dot stimulus fields were set to equal values as were their brightnesses. The durations of the fields are abbreviated S1 and S2; the brightnesses, F1 and F2.

With S1 = S2 = 10 ms and Fb off during stimulus presentations and on for the 1 ms ISI (condition 1), it was found that for a constant Fb (background field brightness), F1 and F2 had to be set at levels almost as bright as Fb for motion to be just seen. However, with S1 = S2 = 10 ms and ISI = 10 ms (condition 2), F1 and F2 had to be set at levels relatively less bright than Fb for threshold data to be obtained (i.e., with F1 = F2 set as for condition 1, discriminations were easy, and it was necessary to reduce F1 and F2). In a rough psychophysical experiment with the experimenter as observer, the correct direction of motion could just be detected in the S1 = S2 = 10 ms case with ISI = 1 ms for a ratio of Fb:F_1 or F_2 = 1.1 (brightness measured in log ft. lamberts); while with S_1 = S_2 = 10 ms, motion could be correctly detected for a Fb:F1 or F2 ratio of 1.6.

In both cases, as the durations S1 and S2 were increased, it was found that motion could be correctly detected at higher Fb:F1 or F2 ratios. That is, one could

perceive motion for Fb relatively brighter than F1 or F2. However, interestingly (and fortunately for the current experiment), this ratio increased more rapidly in the ISI = 1 ms case and for most observers overtook the ISI = 10 ms ratio in the S1 = S2 range between 20 ms and 30 ms. Above this value for S1 and S2, the effects observed for S1 = S2 = 10 ms were reversed, e.g., for S1 = S2 = 40 ms and a constant Fb, motion could be perceived at dimmer F1 = F2 values for ISI = 1 ms than for ISI = 10 ms.

These findings, if examined in a more consistent psychophysical (non hemispheric) study, might yield some interesting results on the relationship between brightness and time (both contributing to stimulus intensity) with respect to motion perception for random dot stimuli.

Under the conditions in which Fb remains on throughout the stimulus presentations (conditions 3 and 4), the Fb:F1 or F2 ratios, for both ISI = 1 ms and ISI = 10 ms, show a very similar progression as the stimulus field durations are increased in the range 10 ms to 30 ms, and this function is close to the one observed for condition 2.

Based on these findings, it was therefore decided to set S1 = S2 = 25 ms and Fb = 1.0 log ft. lambert for all conditions during the experiment proper. All subjects would receive stimulus presentations at these values with the brightness of F1 = F2 set to each subject's individual threshold in pre-trials.

The subjective differences between the four conditions were examined by the experimenter. In condition 1, the fields appeared to flash on just once; in condition 2, the stimulus sequence appeared to flicker due to the longer ISI, while the apparent contrast of the stimuli was slightly lower. On condition 3, the apparent contrast was lower than in conditions 1 and 2. Motion did not appear in a flashing or flickering field as in the previous conditions but was more flowing. The motion in condition 4 was very similar to that of condition 3 while the apparent contrast was very slightly lower.

Apparatus and Procedure II

The four stimulus conditions are represented in Figure 6.1 (not drawn to scale). Total stimulus presentation time is again well within the latency of eye movements.

Subjects received the .75 sec 1 kh warning tone 1 sec before a stimulus presentation was due and they responded by moving the switch in the direction of perceived motion. This response was communicated to and recorded by the experimenter as in previous experiments.

The apparent motion and hemispheric lateralization characteristics of the random dot stimulus cards have been fully described in Experiments 2 and 3. As before, to control for possible visual field biases in the stimulus cards, half of the subjects viewed the cards rotated through 180^{o}.

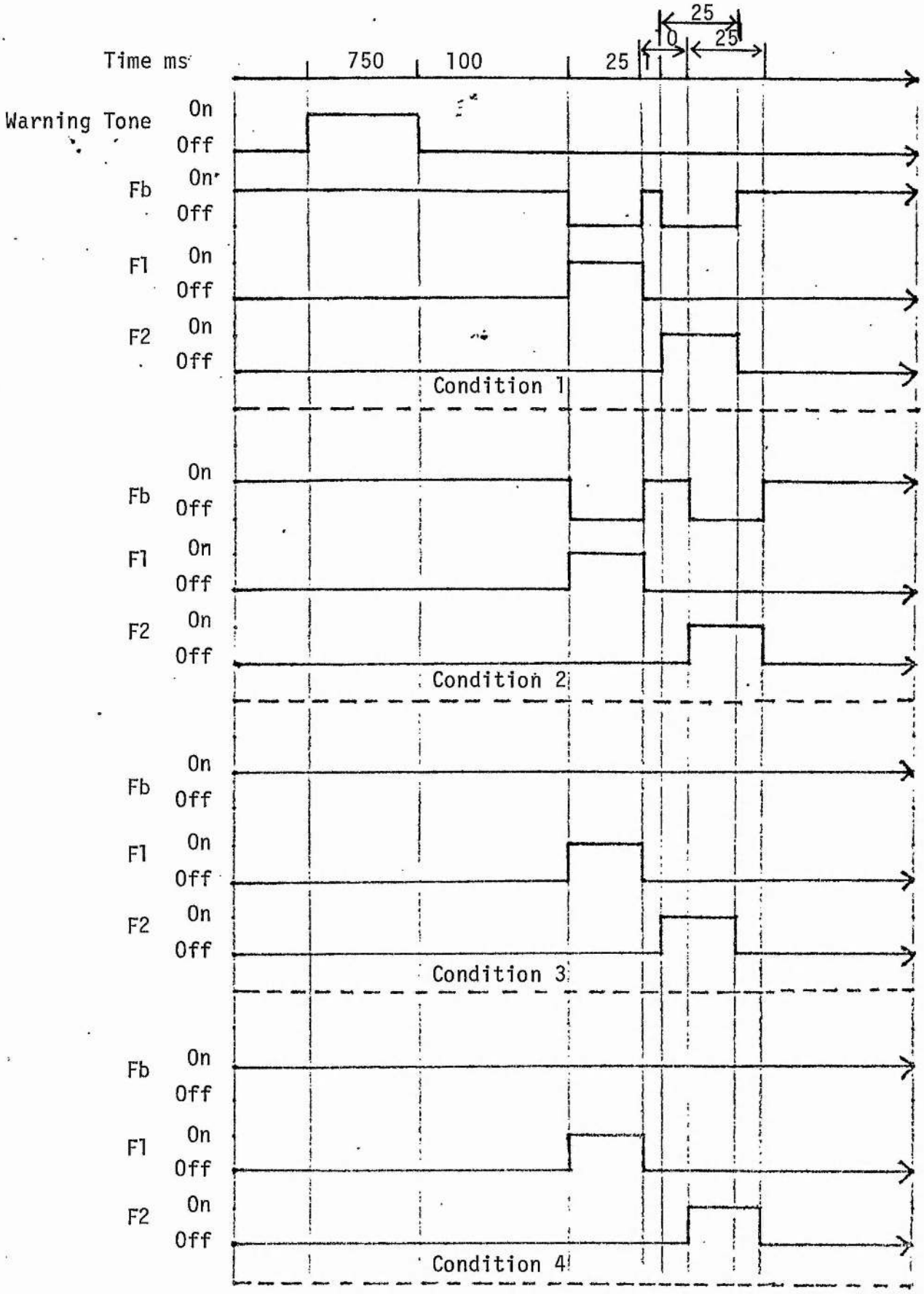


FIGURE 6.1: Experiment Four. Temporal sequence of events for each of the four experimental conditions showing the on/off durations of the background field (Fb) and the stimulus fields (Fl and F2) for each condition.

The random order presentation and response sheets constructed for Experiment 3 were used in an identical manner, with the four current stimulus conditions substituted for the four ISIs of Experiment 3.

Each presentation was made only once and subjects received no feedback as to the correctness of individual responses. A forced choice paradigm was again used with the subject obliged to guess if uncertain as to the direction of motion. So, as previously, the data from subjects with an overall score of less than 97 out of 160 were eliminated from analysis.

For the purpose of data analysis, "trials" is defined in the results section as for Experiment 3, i.e., trial one constitutes presentations 1-32; trial two, presentations 33-96; and trial three, presentations 97-160.

Visual field checks were again conducted (see Experiment 2). No differences were observed. So again we conclude that VF differences which are revealed in the data are not a function of inequitable stimuli presented in the two visual fields.

Subjects

The 16 subjects were 8 adult males (mean age 21.63 yrs, max 33 yrs, min 19 yrs); and 8 adult females (mean age 21.63 yrs, max 24 yrs, min 18 yrs). All were right handed (see results section), and all had normal or corrected vision. All subjects were undergraduate

students at St. Andrews University and had volunteered to participate in an experiment in visual perception.

Four volunteers whose overall score was less than 97 correct out of 160, indicating chance performance, were eliminated from the analyses and replaced by other subjects.

Procedure with subjects

The procedure with subjects was identical to that of Experiment 3, except that during the pre-experimental threshold setting procedure, the stimulus variable manipulated was the (equivalent) brightness of the stimulus fields. With the other experimental variables set as for the experiment proper, the brightnesses of the stimulus fields were reduced from a level at which the subject made no errors to one close to the subject's threshold. The method used was identical to threshold setting for ISI in Experiment 3, with the final brightness level in both stimulus fields equal.

Due to the nature of the four stimulus conditions, the subject was told not to be surprised if some discriminations seemed easier than others.

All other aspects of the experimental procedure were analogous to Experiment 3, with viewings again binocular.

At the completion of Experiment 4, the subject filled out the handedness questionnaire, was asked about sub vocal verbalization and received a denouement as in the previous experiments.

Luminance Levels of the Stimulus Fields

The luminances of the background and stimulus fields were measured for continuous illumination using an SEI spot photometer. The readings for the random dot fields were taken at white items of texture.

For all fields the values presented are the means of a number of readings taken at various points in the field. There were no measurable differences at the various locations, or between the stimulus cards.

During the experiment, the tachistoscope % Intensity scale was set for Fb at 40 = 1.0 log.ft. lambert, while F1 and F2 were adjusted to each subject's individual threshold.

The minimum stimulus field value (F1 = F2) set was 20 on the % Intensity scale, the maximum was 100, with a mean setting for all subjects of 57.5.

In conditions 1 and 2, Fb was off, while F1 or F2 was on; in conditions 3 and 4, Fb remained on throughout the stimulus field presentations. Luminance levels are therefore presented for both situations. Values are given only for settings which were measurably different.

Values

% Intensity Setting for F1 or F2	Condition 1 or 2 Luminance measured in log.ft. lamberts F1 or F2 on alone	Condition 3 or 4 F1 + F2 + Fb (at40)
20	0.2	1.02
30	0.3	
50	0.4	
65	0.5	
80	0.6	
100	0.7	1.1

Fb on alone at a % Intensity setting of 40 = 1.0 log.ft. lamberts.

Results: Experiment Four

Percent correct scores were evaluated for each hand/hemisphere/trial/condition combination for all subjects.

Analyses of variance were performed on these data to test for statistically significant effects. The within subject variables were hemisphere (left and right); hand (left and right); trial (one, two and three); and condition (1, 2, 3, and 4). The between subject variable was sex (male and female).

In the first analysis of variance performed, the data from the four conditions were analyzed so as to clarify the hypotheses regarding the ISI. Specifically examined were ISI duration, i.e., short (conditions 1 and 3), and long (conditions 2 and 4); and ISI type, i.e., those in

which Fb is switched out for the durations of the stimulus fields and on for the ISI (conditions 1 and 2), and those in which Fb remains on throughout the stimulus presentations. The ISIs in conditions 1 and 2 are expected to produce masking. However, in order not to prejudge the issue, we designate the ISI type according to Fb status: conditions 1 and 2 - Intermittent (ISI Int); Conditions 3 and 4 - Continuous (ISI Con).

The mean overall percent correct rate was 78.61%.

The significant main effects were: trial, $p < .02$, table 6.1, figure 6.2, subjects performance fell with increasing trials, indicating a fatigue effect; ISI type, $p < .001$, subjects scored significantly more correct for continuous Fb, 86.72% vs. 70.51% with Fb intermittent, Figure 6.3; ISI duration, $p < .001$, subjects' performance was better for shorter ISIs, 81.97% vs. 75.26% for long ISIs, Figure 6.4. Nonsignificant main effects were hemisphere (left 80.53%, right 76.59%), sex (male 77.15%, female 80.01%), and hand (left 79.17%, right 78.06%).

Significant first order effects were ISI type X ISI duration, $p < .001$, Table 6.2, Figure 6.5, where the main effects for ISI duration may be seen to largely result from differences for intermittent Fb. Significant also was trials X ISI type, $p < .005$, Table 6.3, Figure 6.6, the main effects for trials is mainly due to a fall off in performance over trials when subjects are responding to ISIs with intermittent Fb.

			Male		Female	
Hand	Hem.	Cond.	Mean	SD	Mean	SD
L	L	1	87.50	23.15	93.75	17.68
L	L	2	75.00	26.73	87.50	23.15
L	L	3	75.00	46.29	93.75	17.68
L	L	4	87.50	23.15	87.50	23.15
L	R	1	87.50	23.15	68.75	25.88
L	R	2	81.25	25.88	56.25	32.04
L	R	3	100.00	00.00	93.75	17.68
L	R	4	87.50	23.15	87.50	23.15
R	L	1	93.75	17.68	68.75	37.20
R	L	2	75.00	37.80	62.50	44.32
R	L	3	75.00	37.80	93.75	17.67
R	L	4	75.00	46.29	87.50	23.15
R	R	1	93.75	17.68	75.00	26.72
R	R	2	62.50	44.32	68.75	25.88
R	R	3	93.75	17.68	93.75	17.68
R	R	4	81.25	25.88	87.50	23.15

Table 6.A.

Experiment Four. Summary data. Percent correct Trial One across all subjects. Males (n = 8) and Females (n = 8). The conditions are the four ISIs.

			Male		Female	
Hand	Hem.	Cond.	Mean	SD	Mean	SD
L	L	1	75.00	29.88	87.50	18.90
L	L	2	75.00	26.73	59.38	39.95
L	L	3	93.75	11.57	87.50	23.15
L	L	4	87.50	18.90	93.75	11.57
L	R	1	65.62	22.90	78.12	28.15
L	R	2	68.75	22.16	53.12	20.86
L	R	3	90.62	12.94	87.50	13.36
L	R	4	87.50	13.36	96.88	8.84
R	L	1	90.62	18.60	81.25	29.12
R	L	2	59.38	26.52	81.25	17.68
R	L	3	96.88	8.84	84.38	26.52
R	L	4	78.12	20.86	90.62	18.60
R	R	1	65.62	18.60	75.00	18,90
R	R	2	56.25	29.12	75.00	23.15
R	R	3	71.88	28.15	87.50	18.90
R	R	4	78.12	20.86	93.75	11.57

Table 6.B.

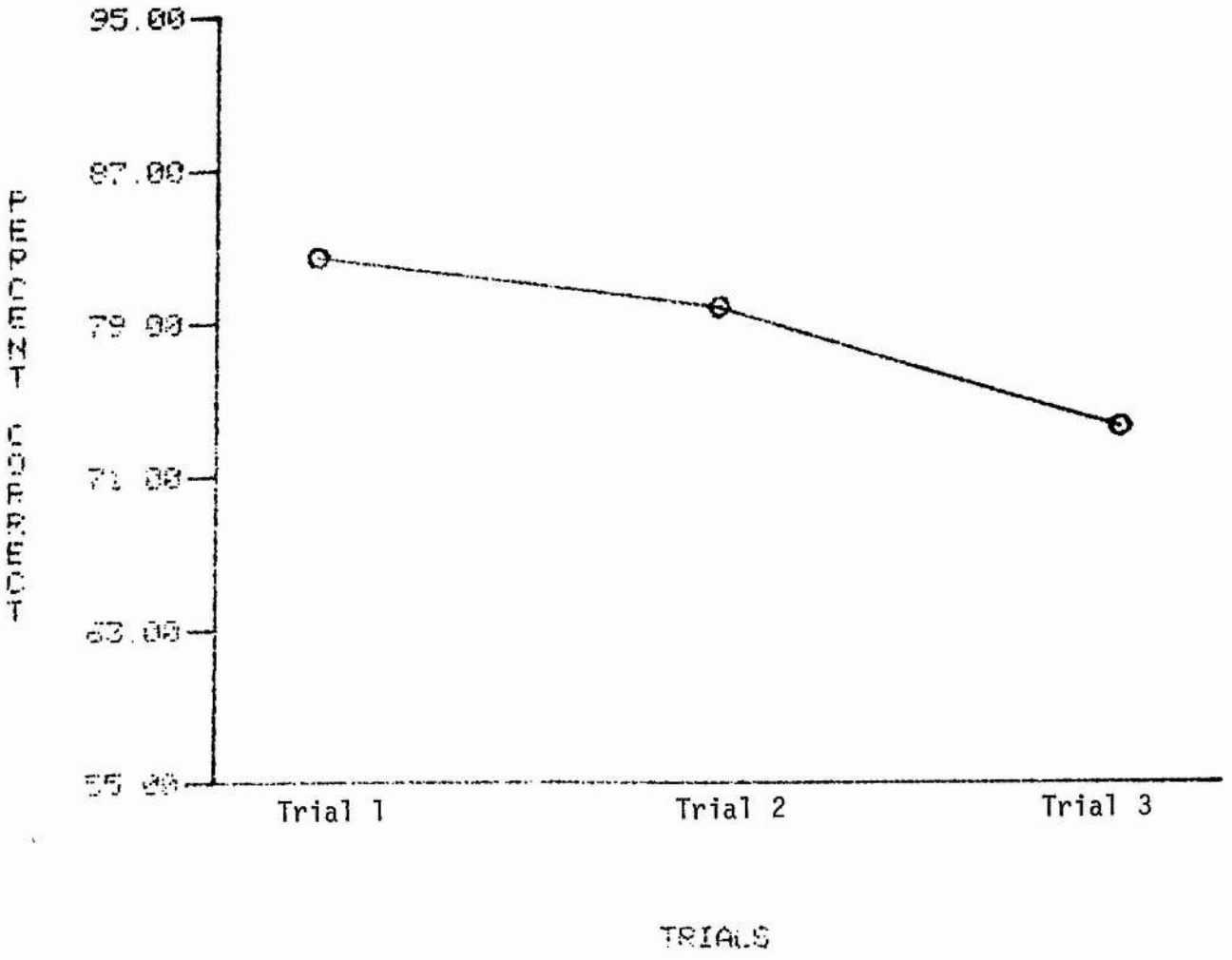
Experiment Four. Summary data. Percent correct Trial Two across all subjects. Males (n = 8) and Females (n = 8). The conditions are the four ISIs.

			Male		Female	
Hand	Hem.	Cond.	Mean	SD	Mean	SD
L	L	1	78.12	28.15	78.12	20.86
L	L	2	43.75	32.04	62.50	26.73
L	L	3	84.38	18.60	84.38	18.60
L	L	4	87.50	13.36	93.75	17.68
L	R	1	53.12	20.86	68.75	37.20
L	R	2	59.38	26.52	43.75	25.88
L	R	3	81.25	17.68	81.25	17.68
L	R	4	78.12	20.86	84.38	22.90
R	L	1	65.62	29.69	71.88	24.78
R	L	2	56.25	22.16	68.75	25.88
R	L	3	81.25	22.16	96.88	8.84
R	L	4	84.38	22.90	87.50	18.90
R	R	1	62.50	23.15	75.00	23.15
R	R	2	50.00	13.36	62.50	26.73
R	R	3	84.38	12.93	81.25	22.16
R	R	4	81.25	17.68	84.38	26.52

Table 6.C.

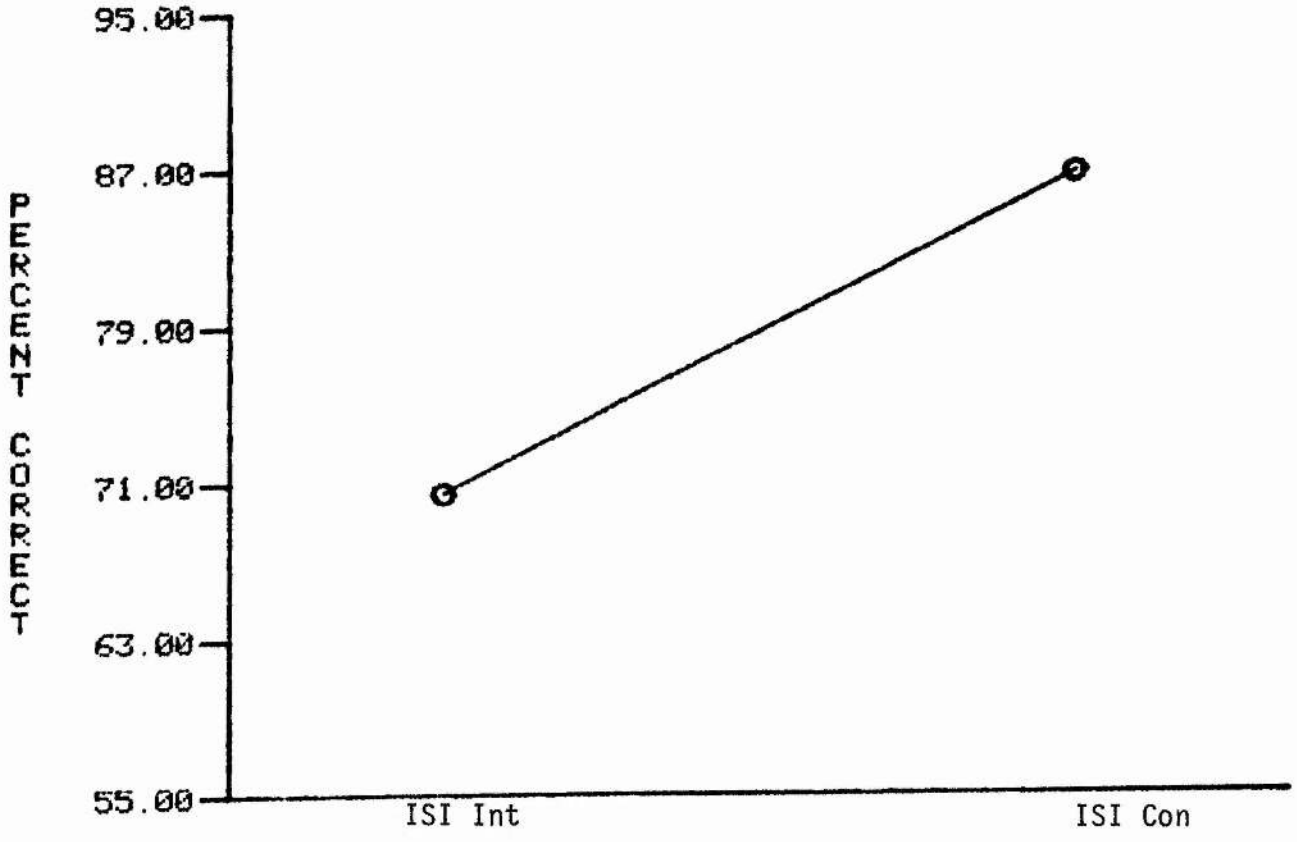
Experiment Four. Summary data. Percent correct Trial Three across all subjects. Males (n = 8) and Females (n = 8). The conditions are the four ISIs.

FIGURE 6.2



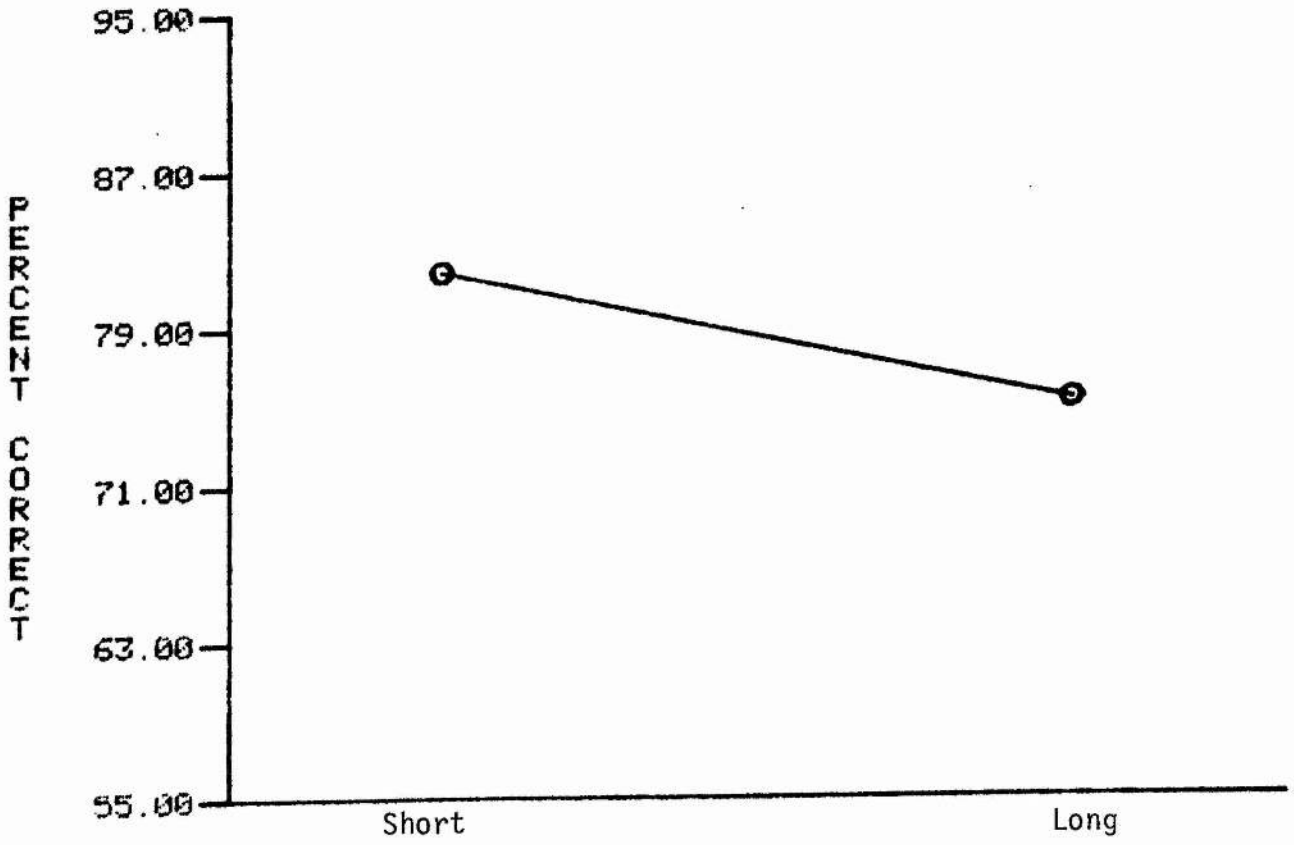
Experiment Four, apparent motion of random dot stimuli. Fall in percent correct over trials.

FIGURE 6.3



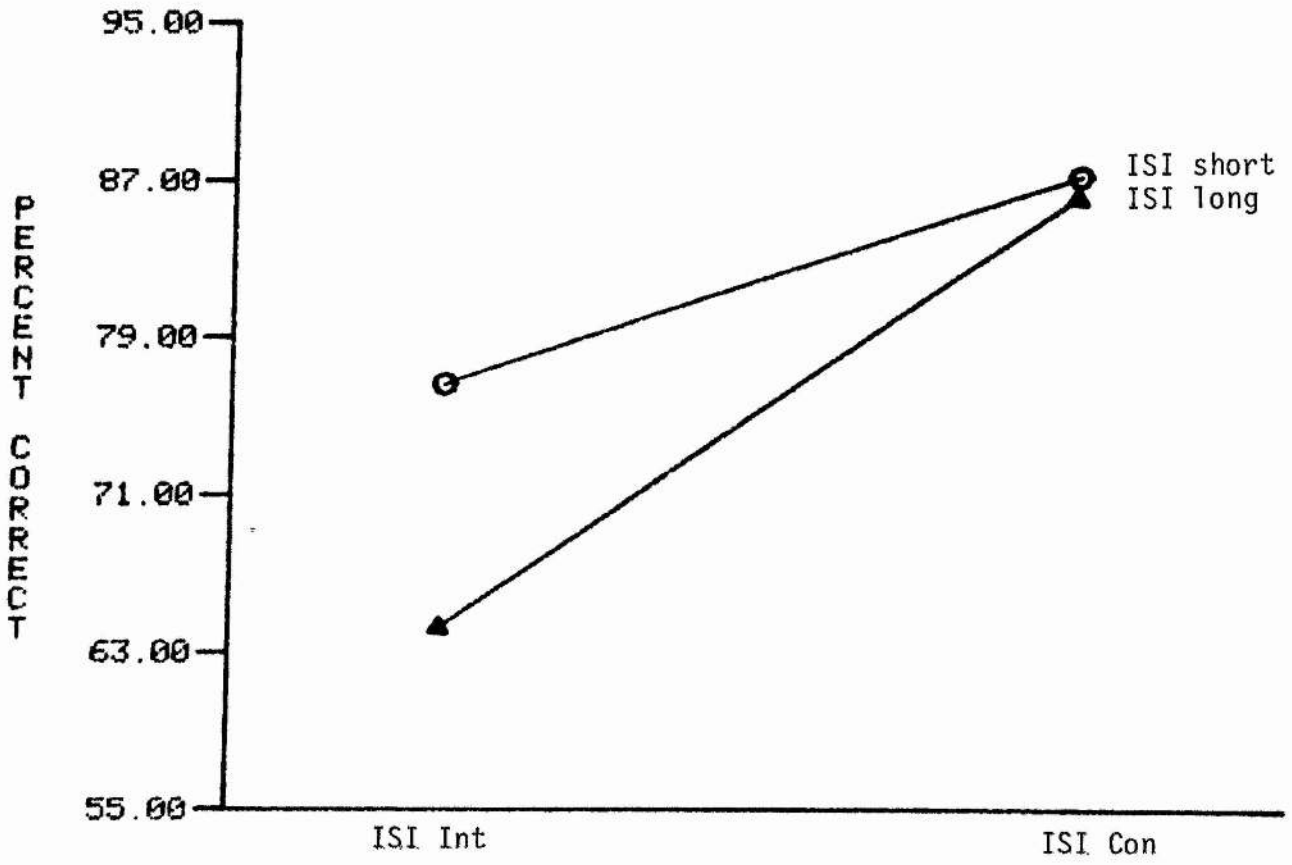
Experiment Four. Difference in percent correct for the two ISI types. For ISI Cons. the background field remained on throughout stimulus presentations. For ISI Ints. the background field was switched off during stimulus field presentations and on for the ISI.

FIGURE 6.4



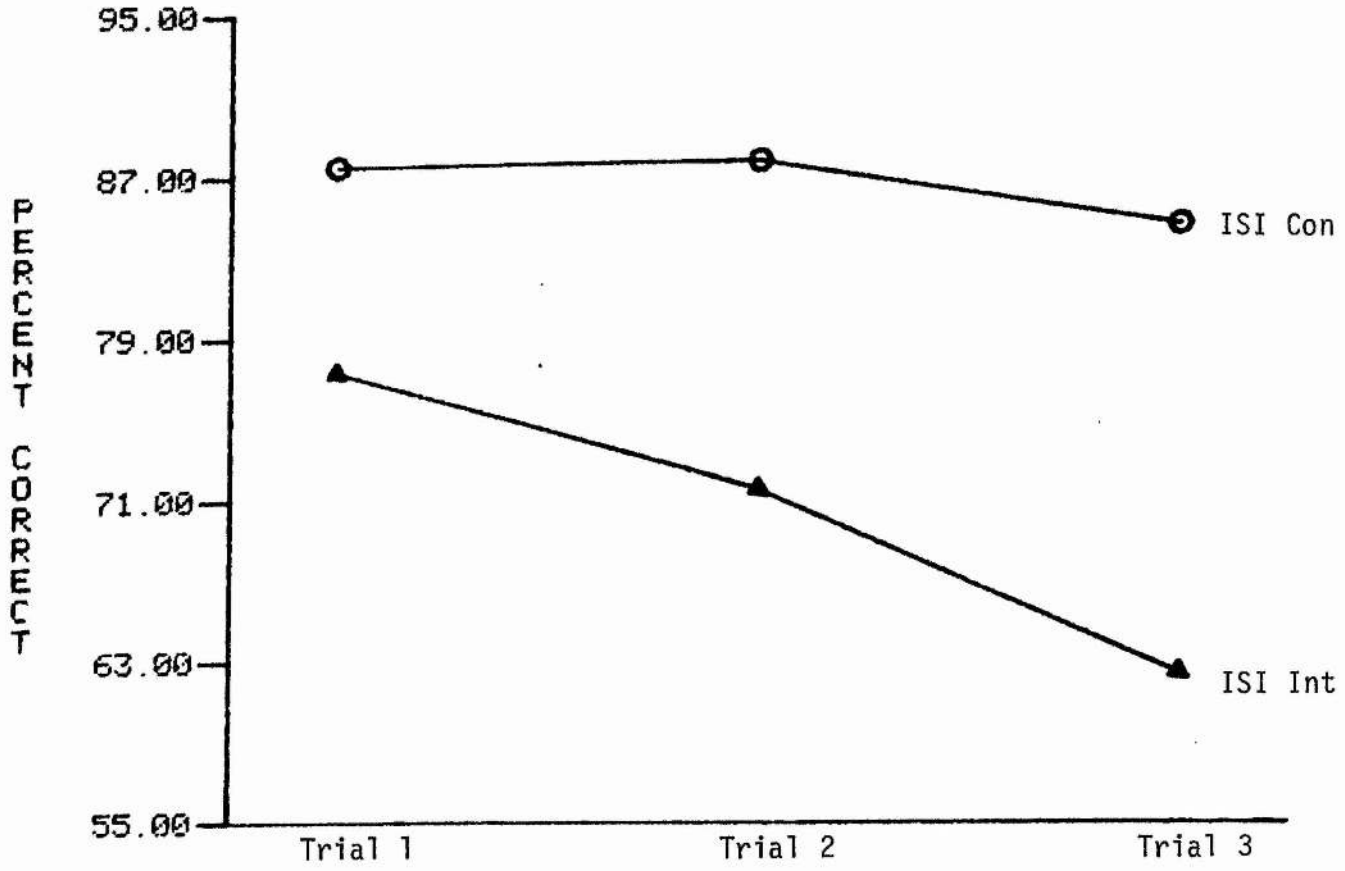
Experiment Four. Effect of ISI duration on percent correct scores.

FIGURE 6.5



Experiment Four. The ISI type X ISI duration interaction. Percent correct scores are particularly depressed for long ISI Int. Duration has little effect on ISI Con. scores.

FIGURE 6.6



Experiment Four. Change in percent correct scores over trials for the two ISI conditions. The linearly falling ISI Int. scores contrast with the virtually constant ISI Con. scores.

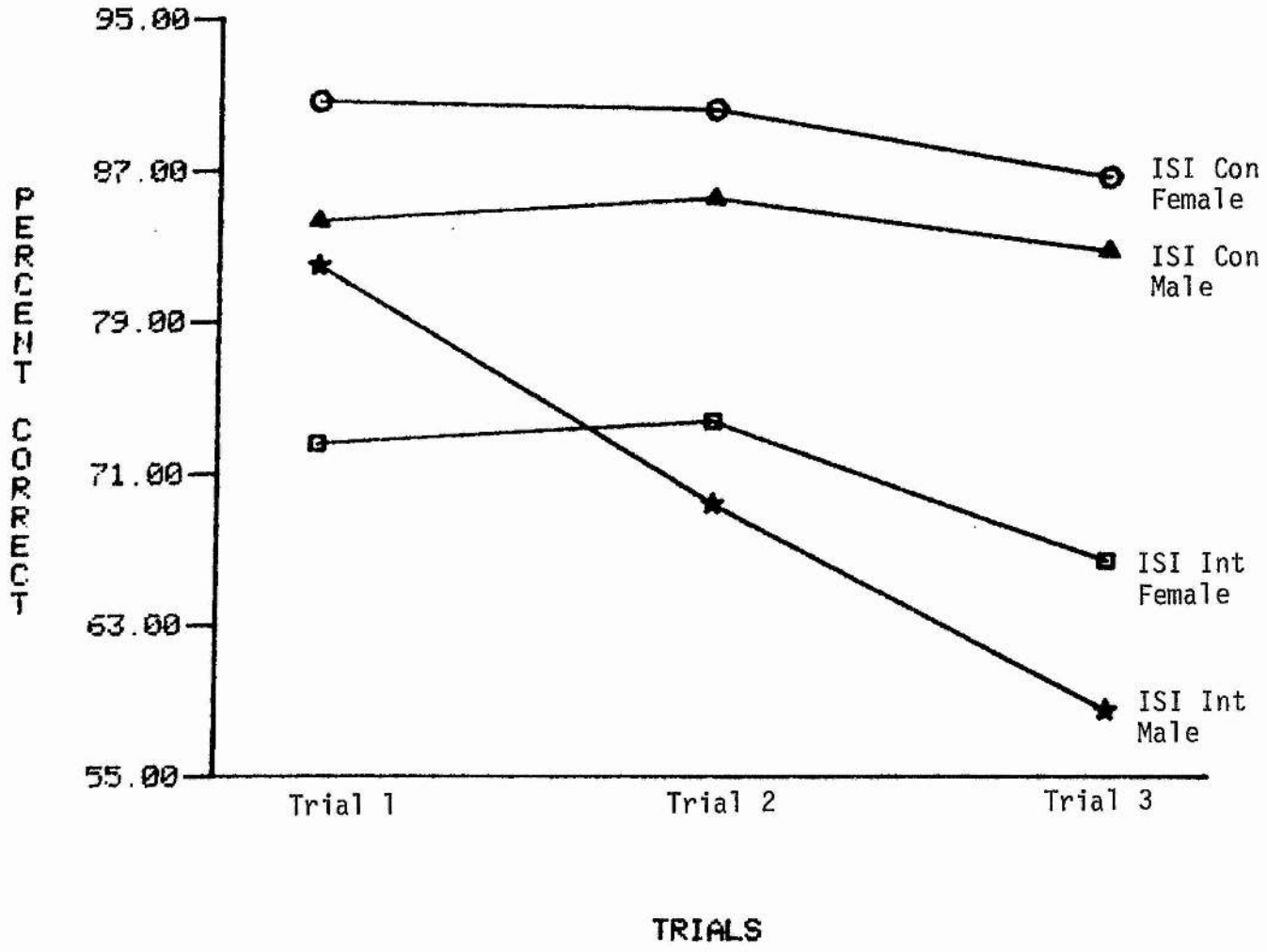
No other first order interactions were statistically significant.

A significant triple interaction was trials X ISI type X sex, $p < .01$, table 6.4, figure 6.7. With intermittent Fb, male % correct scores fall more over trials.

The only other significant triple interaction was hand X hemisphere X sex, $p < .005$, table 6.5, figure 6.8.

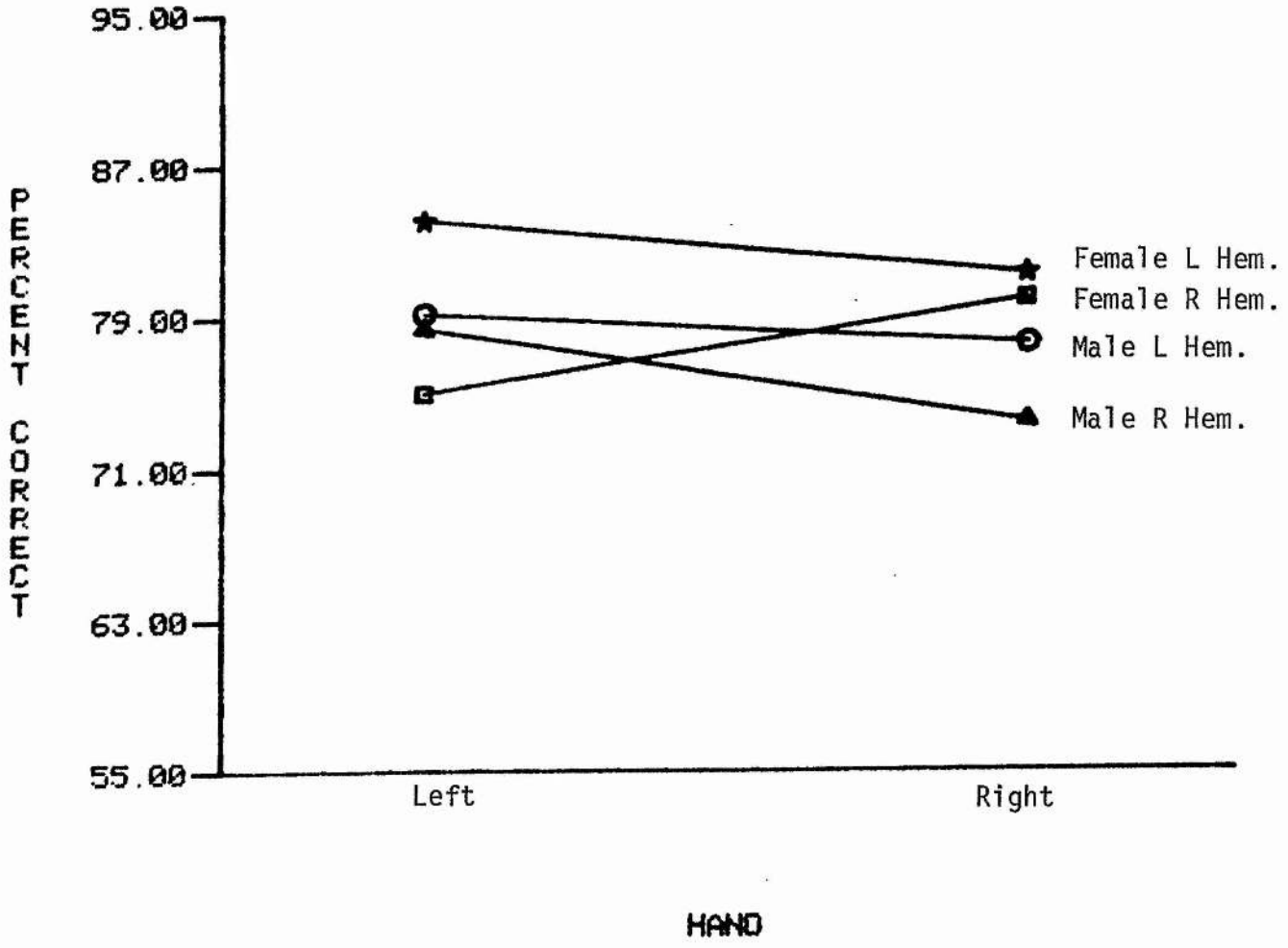
Under particular study in this experiment were the effects which the ISI has on the cerebral hemispheres. This is illustrated in figure 6.9, table 6.6. It can be seen that there is no difference between the hemispheres for continuous Fb ISIs (conditions 3 and 4), irrespective of ISI duration. However, there appears to be a left hemisphere superiority for the ISIs in which Fb is interrupted (conditions 1 and 2). The analysis of variance revealed no ISI duration X hemisphere effects, indicating that over all conditions, the hemispheres were not differentially affected by the length of the ISI. However, hemisphere X ISI type came close to significance, $p = .06$, table 6.7, figure 6.10. The left hemisphere performs better than the right in conditions 1 and 2. The interaction (figure 6.10) appears to have failed to reach significance due to the slight left hemisphere superiority which was also observed in conditions 3 and 4.

FIGURE 6.7



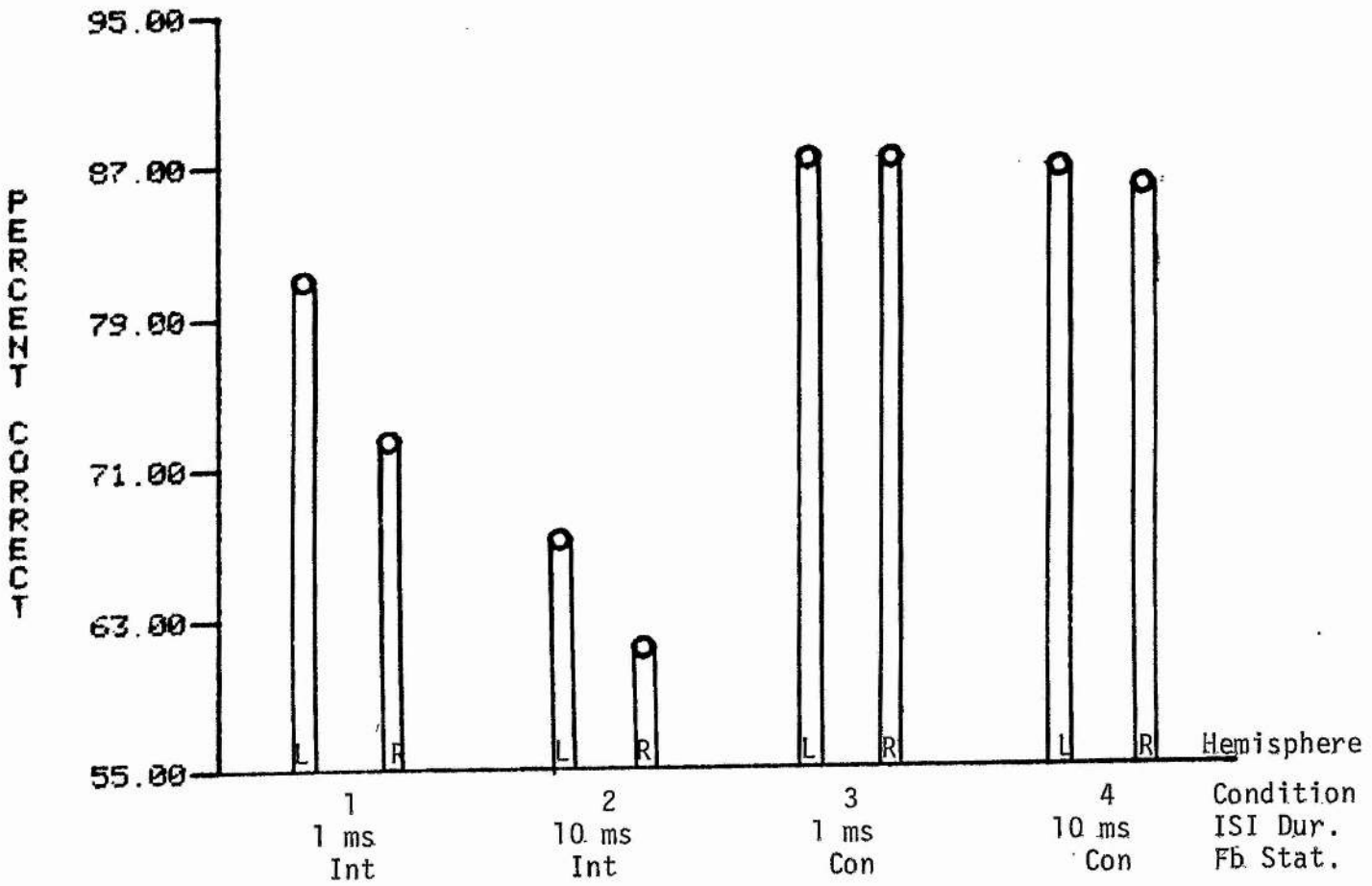
Experiment Four. ISI type X Sex X Trials significant interaction.

FIGURE 6.8



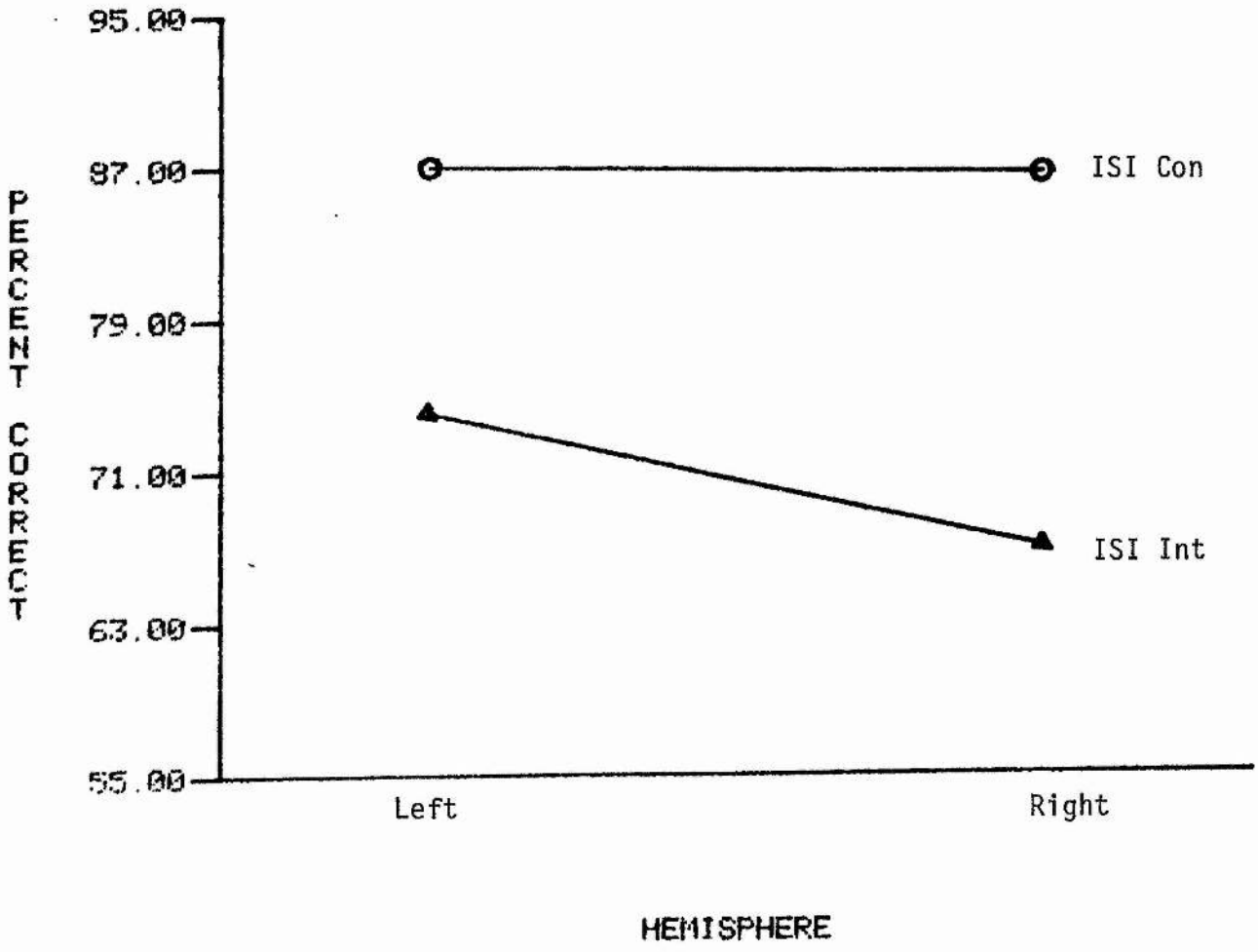
Experiment Four. Hemisphere (contralateral VF) X Hand X Sex significant interaction. The female right hemisphere data goes against the general trend.

FIGURE 6.9



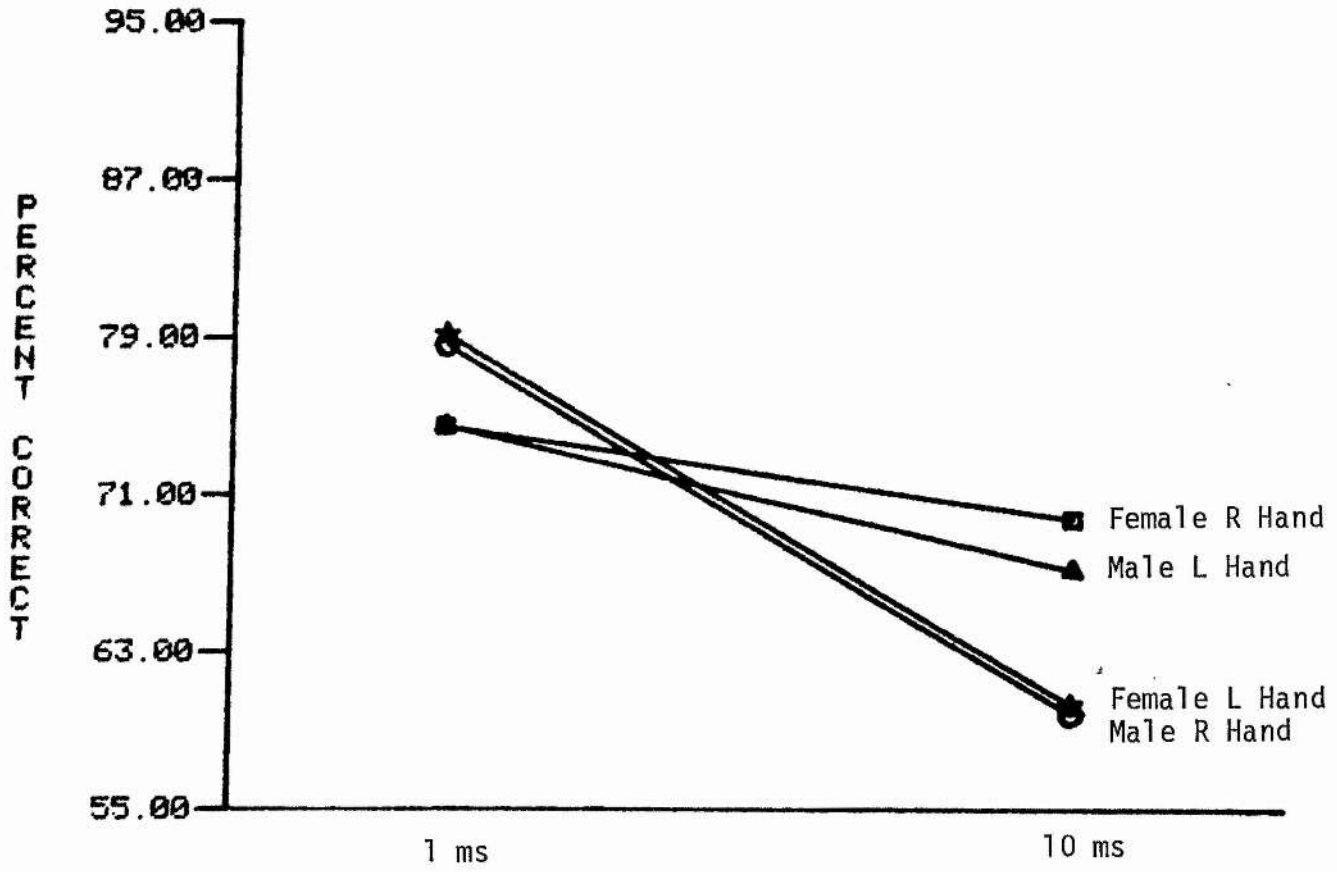
Experiment Four. Hemispheric differences in percent correct for the four experimental conditions. The left hemisphere superiority for the ISI Int. conditions contrasts with the similarity of hemispheric scores for the ISI Con. conditions.

FIGURE 6.10



Experiment Four. A comparison of hemispheric performance for the two ISI types.

FIGURE 6.11



Experiment Four. Significant Hand X ISI duration X Sex effect for Conditions 1 and 2 (ISI Int.). The sexes differ in which hand gives higher percent correct scores at the two ISI durations.

To examine more carefully the effects of ISIs with intermittent Fb, an analysis of variance was performed using the data from conditions 1 and 2.

The mean percent correct response rate for these conditions was 70.51%.

The significant main effects were trials, $p < .005$, Table 6.3 (ISI Int), Figure 6.6 (ISI Int); ISI duration, $p < .001$, Table 6.2 (ISI Int), Figure 6.5 (ISI Int). For these conditions, hemisphere was significant, $p < .05$, the left scored 74.09% correct, the right 66.93%, Table 6.7 (ISI Int), Figure 6.10 (ISI Int). There were no significant effects for sex (male 70.06%, female 70.96%), or hand (left 70.32%, right 70.70%).

There were no significant first order effects.

The only significant triple interaction was hand X ISI duration X sex, $p < .025$, Table 6.8, Figure 6.11. The sexes being opposite in which hand showed the greatest fall with increasing ISI.

For conditions 1 and 2, five of the eight male subjects and five of the eight females were left hemisphere superior (left hemisphere-right hemisphere scores). One male showed no difference.

The mean right handedness score for males was 2.31, S.D. .51; for females 2.45, S.D. .39; for all subjects, 2.38, S.D. .44.

Seven males and two females reported that their responses were <u>not</u> mediated by sub-vocal verbalization. Subjects' right hemisphere scores were subtracted from

their left hemisphere scores and a t test performed on these data which compared the "yes" sub-vocal verbalization group with the "no" group. Although the mean L-R difference was greater for the "yes" sub-vocal verbalization group, the difference did not reach statistical significance (t = 1.1, df = 14).

	Percent Correct
Trial 1	82.42
Trial 2	79.79
Trial 3	73.63

Table 6.1

	Percent Correct	
	ISI Con.	ISI Int.
ISI short	87.24	76.69
ISI long	86.20	64.32

Table 6.2

	Percent Correct	
	ISI Con.	ISI Int.
Trial 1	87.50	77.34
Trial 2	87.89	71.68
Trial 3	84.77	62.5

Table 6.3

		Percent Correct	
		ISI Con.	ISI Int.
MALE	Trial 1	84.38	82.03
	Trial 2	85.55	69.53
	Trial 3	82.80	58.59
FEMALE	Trial 1	90.63	72.66
	Trial 2	90.23	73.83
	Trial 3	86.72	66.41

Table 6.4

		Percent Correct	
		Left Hem.	Right Hem.
MALE	Left hand	79.17	78.39
	Right hand	77.60	73.44
FEMALE	Left hand	84.11	75.00
	Right hand	81.25	79.95

Table 6.5

	Percent Correct	
	Left Hem.	Right Hem.
Condition 1	80.99	72.40
Condition 2	67.19	61.46
Condition 3	87.24	87.24
Condition 4	86.72	85.68

Table 6.6

	Percent Correct	
	Left Hem.	Right Hem.
ISI Con.	86.98	86.46
ISI Int.	74.09	66.93

Table 6.7

	Percent Correct	
	Left Hand	Right Hand
MALE ISI 1 ms	74.49	78.65
MALE ISI 10 ms	67.19	59.90
FEMALE ISI 1 ms	79.17	74.48
FEMALE ISI 10 ms	60.42	69.79

Table 6.8 Conditions 1 & 2

Discussion

The experiment was an apparent motion study, using random dot stimuli, designed to examine the differential effects of ISI parameters on the two cerebral hemispheres. Also under scrutiny was whether the results obtained from male and female subjects differed. These points were raised by the outcome of Experiment 3.

The results of Experiment 3 and the work of Braddick (1973) have suggested that for random dot stimuli a bright ISI may act as a masking stimulus for motion. Braddick (1973) compared the effects of a dark vs. a bright ISI; the current experiment compares an ISI for which Fb remains on throughout the stimulus presentations forming a continuous background, vs. an ISI for which Fb is switched out during the presentation of the random dot fields and on for the ISI. The latter is the same as Braddick's bright ISI condition. Braddick (1973) found that increasing the duration of the bright ISI increased the masking effects. This was also studied in our experiment.

The results of Experiment 4 show highly significant ISI results. Subjects scored significantly more correct for ISIs in which Fb is continuous (ISI Con.) compared to ISIs for which Fb is interrupted during the stimulus presentations and switched on for the ISI (ISI Int.), figure 6.3. Subjects scored more correct for shorter ISIs, figure 6.4. However, the effect of ISI duration is shown to result from the pronounced difference in percent

correct for ISI Int., figure 6.5. In the ISI Con. situation (experimental conditions 3 and 4), no significant difference seems to result from increasing the ISI duration from 1 ms to 10 ms, table 6.2. But there is a marked reduction in percent correct for ISI Int. = 1 ms and an even greater reduction for ISI Int. = 10 ms.

It appears that for random dot apparent motion stimuli, ISI Int.s act as masks to motion, and the masking effect is enhanced by increasing the duration of the ISI Int. ISI Con.s on the other hand appear not to act as masks (or are much less effective), while increasing ISI Con. duration does not reduce the likelihood of correctly detecting the direction of motion (at least in the range of ISI Con. studied).

We have no data to compare our ISI Con. conditions with Braddick's (1973) ISI dark conditions. Whether motion is perceived for the same ISI durations under the two conditions might make an interesting psychophysical study.

However, it appears that in our experimental conditions 1 and 2 with ISIs involving an intermittent Fb, the percept of apparent motion is upset.

This effect does not result from a reduction in the contrast of the patterned stimuli by the ISI making them less discernible, since in conditions 3 and 4 with a constant background field the apparent contrast of the patterns was visibly lower (see pilot studies) and the stimuli appeared more washed out. Rather it is the abrupt intensity change in the stimulus display, which occurs in conditions 1 and 2 when the ISI is switched on in between

the stimulus fields, which disrupts the percept of motion.

All conditions were subjectively well above threshold luminance. In conditions 3 and 4, since Fb remains on, the overall luminance is greater than in conditions 1 and 2. However, the results cannot be accounted for in terms of luminance since performance is poorest in condition 2 which has a longer bright ISI than condition 1. Braddick (1973) also experimentally rejected contrast and luminance as explanations for his results.

Unlike Experiment 3 in which subjects improved their performance after trial one, in the current experiment there was a fall in percent correct over trials (figure 6.2). This is seen to result from increasingly poor performance for ISI Int. (figure 6.6). The masking ISI has a more fatiguing effect on the visual system than the non-masking ISI, and for no readily apparent reason this fall in performance for ISI Int. is more dramatic for male subjects (figure 6.7).

As in Experiment 3, hands was nonsignificant; also nonsignificant were any double interactions involving hands. Therefore, we draw the same conclusions as previously.

The results of Experiment 3 suggested that the hemispheres might differ in their susceptibility to a masking ISI. The outcome of Experiment 4 confirms this conjecture. Figure 6.10 shows that for ISI Con. (non-masking ISIs), there is no difference between the performance of the hemispheres. For ISI Int.s however, the result predicted by Experiment 3, a left hemisphere

superiority, was observed. This effect was shown to be significant, $p < .05$, when the data from conditions 1 and 2 were analyzed.

In Experiment 3, it also appeared that males might perform better overall, and that the left hemisphere superiority might maintain only for female subjects. (Although these predictions were made with reservations due to the differences in sample sizes and the variance of the males' data in Experiment 3.)

Over all conditions in Experiment 4, there were no significant sex or sex X hemisphere effects; nor were there any for conditions 1 and 2. These results indicate no difference between the sexes in susceptibility to a masking vs. a non-masking ISI; in addition, there were no ISI duration effects which differentiated the sexes in Experiment 3. The significant sex effects which were observed in Experiment 3 therefore seem to have resulted from using a comparatively small sample of males.

In Experiment 4, two triple interactions involving sex and hand were significant. In conditions 1 and 2, sex X hand X ISI duration, $p < .025$, figure 6.11. For males, the right hand was superior to the left for ISI = 1 ms, and inferior at ISI = 10 ms; for females, this pattern was reversed (figure 6.11). In a population of right handed subjects, the reason for this effect is not clear. The interaction was not significant over all four conditions.

The other significant triple interaction, sex X hand X hemisphere, $p < .005$, Figure 6.8, was observed in the analysis of all four conditions (but did not attain significance in the analysis of Conditions 1 and 2). For

both sexes, the left hemisphere is superior with the left hand giving higher scores for this hemisphere. This is a surprising result as one would have expected more interference in response output, if there were any, to have occurred in the longer pathway, i.e., left hemisphere receiving, left hand responding. In addition, all subjects were right handed which would have led one to expect generally fewer errors with the dominant hand. However, the triple interaction clearly occurs due to the right hemisphere data. For males, as might be expected, there are fewer right hemisphere errors when using the left hand; whereas for females, the converse is the case. Other than observing that the females gave slightly higher right handedness scores than the males (2.31 vs. 2.45), we have no ready explanation for this interaction.

With regard to sub-vocal verbalization, although the difference left hemisphere score minus right hemisphere score, for conditions 1 and 2, was on average greater for subjects who reported using sub-vocal verbalization, the difference between the two groups ("yes" vs. "no" sub--vocal verbalization) did not attain statistical significance.

We have observed that the right hemisphere is more susceptible to the effects of a masking ISI. With no significant difference, in the current experiment, between the hemispheres for non-masking ISIs.

The data from conditions 1 and 2 show that as the duration of the masking ISI is increased, the masking effect is also increased (figure 6.5). However, the lack of a hemisphere X ISI interaction for these conditions shows that this increase in overall masking does not affect the hemispheres differentially (figure 6.9, conditions 1 and 2). This would imply that the effect of masking ISI duration is peripheral, since overall the percent correct falls with masking ISI increase, while the performance of the hemispheres (the central component) falls proportionally. [The ratio L hem. % correct/ R hem. % correct, for condition 1 = 1.12; for condition 2 = 1.09.] Yet the finding of a hemispheric difference shows an ultimate central effect.

Given a degraded or interrupted stimulus from the peripheral sensory system, the left hemisphere seems better able to output an accurate percept of apparent motion; but the right is no worse proportionally when the overall masking effect is increased.

Other research indicates the peripheral nature of a uniform light field acting as a masking stimulus. Braddick (1973) failed to obtain dichoptic masking for a bright ISI. And in backward masking experiments forms are not masked by dichoptically presented homogeneous flashes of light (Mowbray & Durr, 1964; Schiller & Wiener, 1963; Smith & Schiller, 1966).

The current study does not, of course, preclude an additional entirely central differentiation between the hemispheres in the detriments to motion perception caused by a masking ISI. A dichoptic vs. binocular hemispheric study could separate out some of the peripheral and central aspects of such masking. The work of Turvey (1973) suggests that an ISI containing a random dot pattern of the same texture density but uncorrelated with the stimulus patterns (i.e., a field which requires the same type of perceptual analysis as the stimuli) would produce dichoptic masking under conditions in which a bright ISI would not.

However, having confirmed the prediction of Experiment 3 that the left hemisphere would outscore the right under masking ISI conditions, we will now proceed to study some other potential differences between the hemispheres in their response to motion stimuli. In the next chapter, we will examine figures which appear to move outside the stimulus plane.

CHAPTER 7

Experiment 5. Apparent motion in the third dimension.

Introduction

Early in the study of apparent motion, it was reported that motion may be readily observed between different geometric line drawings. The percept is typically that the first shape, e.g., a square, undergoes a deformation during its apparent trajectory to take up both the position and shape of the second figure, e.g., a circle. The deformation is plastic and in the plane of the figures. In the special case where the shapes are identical in contour, but differ in orientation, an additional percept (seldom spontaneously reported for other pairs of figures) is frequently observed-- the shape appears to rotate in depth to take up its second position (Wertheimer, 1912; Steinig, 1929; Fernberger, 1934; Orlansky, 1940). This effect may be illustrated by the simple case of a V shaped figure (Neuhaus, 1930), presented as stimulus one (S1) in orientation ^, and as S2 in orientation V, with the end points of S1 and S2 contiguous, thus: 

With S1 presented temporally prior to S2, and with durations of S1, ISI, and S2 such that apparent motion is observed, the percept may be of the ^ undergoing a plastic deformation in the stimulus plane to take up the S2

position; or rotating in depth about the common contact points into position S2. Generally, as the total duration S1 + ISI + S2 is increased from minimum values, more rotations in depth are reported.

Analogous percepts occur for more complex figures, e.g., right angled trapezoids (Kolers & Pomerantz, 1971).

It should be noted that binocular streopsis is not necessary for these depth effects--Kolers and Pomerantz's subjects viewed their stimulus display with the right eye only. During the experiment to be reported, subjects viewed the stimuli binocularly.

The clinical studies reviewed in Chapter One indicate that although disorders of depth perception are more frequently observed for bilateral lesions, when damage is unilateral, the lesion site tends to be in the right hemisphere (Riddoch, 1917, 1935; Homes, 1919; Brain, 1941; Paterson & Zangwill, 1944; Carmon & Bechtoldt, 1969; Benton & Hecaen, 1970; Rothstein & Sacks, 1972; Lehmann & Walchli, 1975; Danta et al., 1978; Hamsher, 1978).

In tachistoscopic studies with normal subjects, Durnford and Kimura (1971) observed a right hemisphere superiority for binocular but not monocular viewings of rods in depth. They also found the right hemisphere to be more accurate for depth judgments in Julesz stereograms. However, Richards (1970) reports greater left hemisphere accuracy for the judgment of depth of briefly presented polarized lines.

Both the clinical and experimental literature therefore appear inconclusive as to which hemisphere is dominant for the various forms of depth perception.

Using the V shaped stimuli described earlier, it is possible, by manipulating the stimulus durations and/or ISI, to produce two different percepts of motion: movement either in the plane of the stimuli, or in three dimensional space. "Plane" responses predominate for short S1 + ISI + S2 durations and the frequency of "space" responses increases as the total presentation time is lengthened.

This experiment considers whether, as total presentation time increases, the left and right hemispheres change from "plane" responses to "space" responses at different points on the S1 + ISI + S2 continuum. Thus we may study the decision parameters of the two hemispheres with respect to the perception of motion in depth.

Apparatus and Procedure

The experiment was conducted in the same experimental room as Experiment 2, and utilized the same three field tachistoscope (with the neutral density gelatin filters in place in the stimulus fields), response switch, electronic response display, headphones and warning tone. (See the Apparatus and Procedure section of Experiment 2 for a complete description of the equipment.)

Fb, the fixation field, contained the same fixation card as previously, a centrally positioned 1/8 in. diameter black fixation spot on a white background.

The stimuli were drawn on four 6 in. x 4½ in. rigid white cardboard cards.

Again, when viewed in the tachistoscope, 1 in. on a card = 3^{o} visual angle.

The V shaped stimuli were made up from 1 in . lengths of 1/32 in. thick Lettreset lines. The two topmost points on the arms of Vs were on the same vertical level as the fixation spot, as were the lowest points on the arms of Λs. The nearest of these two points on a stimulus figure was 1 in, 3^{o} visual angle (VA) horizontally from fixation, the furthest point 2 in. 6^{o} VA. The apex of a stimulus figure was 1/2 in. vertically above (or below) a point at a horizontal displacement of 1-1/2 in., 4-1/2^{o} VA, from fixation.

The cards are shown schematically in figure 7.1.

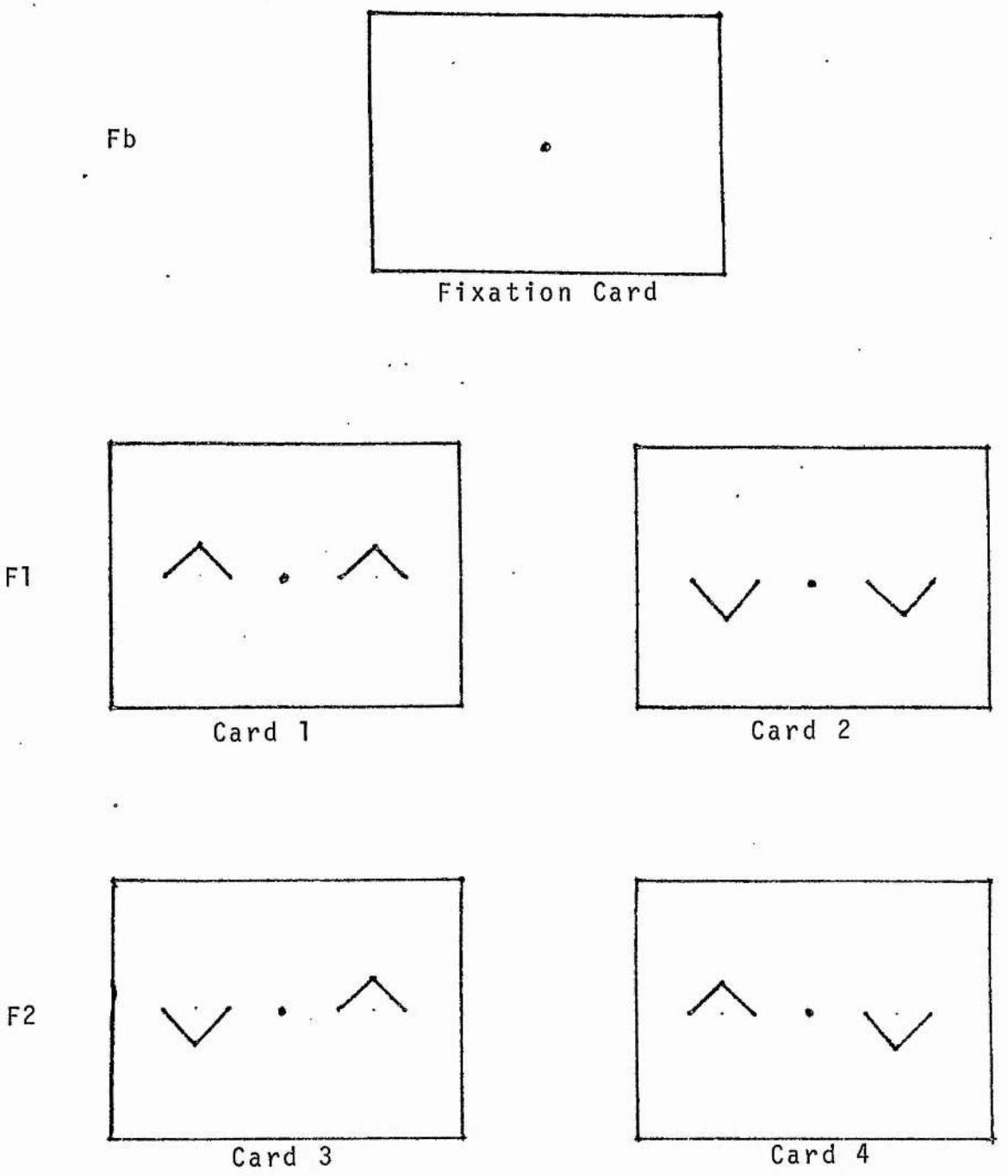


Figure 7.1

Experiment Five. Diagram of stimulus cards. The fixation card is placed in the background field (Fb) of the tachistoscope, cards 1 and 2 in tachistoscope field 1 (F1) and cards 3 and 4 in tachistoscope field 2 (F2). During a stimulus presentation a V appears to move up or down in the left or right visual field.

The dot equivalent to the fixation spot on the stimulus cards in the figure was not present on the actual cards. It is presented here as a reference point. A copy of the stimuli appears in Appendix B.

Considering card 2 and card 4 switched on simultaneously so that they are superimposed, reveals that the Vs in the right visual field (RVF) will occupy the same position to appear as a single V, while the V in the LVF of card 2 and the /\ in the LVF of card 4 will meet to form a diamond with one inch sides.

Now with the fields programmed to switch in the sequence Fb, F1, Fb, F2 (with card 2 in F1 and card 4 in F2) and timed so as to produce apparent motion, the V in the RVF appears stationary, while the V in the LVF appears to move into a /\ position, i.e., upwards motion occurs in the LVF. Similarly pairing card 2 in F1 with card 3 in F2 produces upwards motion in the RVF, while the LVF V remains stationary.

So, with F1 always presented temporally prior to F2, the stimulus cards may be presented to produce upwards or downwards motion in the left or right visual field.

That is:

Field 1 Card Presented	Field 2 Card Presented	Motion Direction	Motion Visual Field	Hemisphere Stimulus
1	3	down	left	right
1	4	down	right	left
2	3	up	right	left
2	4	up	left	right

Table 7.1

There is no information available to the subject from the first card presented as to the side on which motion will occur, also with a stimulus shape presented in each visual field, his attention will not tend to be distracted to one side. Note also that on the first card presented (card 1 or card 2), the stimulus shape in the LVF occupies the same vertical displacement as the shape in the RVF, i.e., they are both V or Λ, and both below or above the horizontal line through fixation. This decreases the possibility of the subject's attention being drawn diagonally from fixation, either to the left or right.

Each subject viewed equal numbers of downward moving as upward moving stimuli in each visual field in order to control for any spurious effects which may have resulted from the presentation of an unbalanced sequence.

It is possible for the subject to work out that when card 1 appears first, motion will be downwards, and when card 2, upwards. However, as in this experiment subjects (none of whom had participated in previous experiments)

were not required to detect the direction of motion, the decision being motion in the "plane" or in "space", it is unlikely that it would have occurred to anyone to notice this. Even in the remote case of a subject becoming aware of this property of the stimuli, especially given the short presentation times of S1, it would not have influenced the experimental results.

It is only when the second card of a pair is presented that information for motion becomes available to the subject, with the perception being of a V (or ∧) shaped figure moving to occupy its second position in one visual field, while in the other VF the stimulus shape remains stationary. Motion is either upwards or downwards for a particular presentation and is symmetrical about a horizontal line through fixation.

In the tachistoscope, the nearest point of a stimulus shape is 3^{o} VA from fixation, the furthest point 6^{o} VA, while the apex of the V moves through a point $4\text{-}1/2^{o}$ VA horizontally from fixation. Therefore with the subject foveally fixating the central spot of the fixation card, the moving stimuli are lateralized to either the left or right cerebral hemisphere.

It was necessary for the stationary Vs in sequentially presented cards to overlap exactly and for the end points of the arms of moving Vs to be contiguous, to eliminate the possibility of motion in the former case and to produce motion about a common axis in the latter.

The cards were therefore made to fit tightly into the cardholders of the tachistoscope to avoid misalignments as the cardholders were moved between presentations to position a different card in the stimulus field. Prior to running each subject, the stimuli on pairs of cards were lined up visually by the experimenter, viewing the superimposed or contiguous stimuli with F1 and F2 switched on simultaneously and continuously. These alignments were then finalized by the experimenter observing the stimuli under the more sensitive criterion of optimum apparent motion.

As in previous experiments, to control for any biases either in the stimulus cards or in the tachistoscope fields, for part 2 of the experiment, the cards were rotated through 180^{o} (turned upside down) and replaced in the same cardholders.

This results in:

Field 1 Card Presented	Field 2 Card Presented	Motion Direction	Motion Visual Field	Stimulated Hemisphere
1	3	up	right	left
1	4	up	left	right
2	3	down	left	right
2	4	down	right	left

Table 7.2

Comparing Table 7.1 and 7.2 shows that the pairs of cards now produce the opposite direction of motion in the "opposite" visual field.

As in previous experiments, half of the subjects (matched for sex and responding hand used first) viewed the cards orientated as in Table 7.1, the other half, Table 7.2.

The .75 sec duration, 1 kh tone, presented through stereo headphones with equal intensity to each ear 1 sec prior to a stimulus presentation, alerted subjects that a trial was due and they should fixate the spot.

During the experiment, Fb, the fixation field, remained on except while F1 and F2 were being presented. The following field sequence, programmed on the tachistoscope timing unit, produced apparent motion of the required perceptual properties.

(The rationale for choosing these particular stimulus durations is discussed in the next section - Pilot Studies and Selection of Stimulus Parameters.)

One second after the warning tone, with the subject fixating the central spot on Fb, F1 is switched on presenting the stimulus card in F1 for 30 ms (stimulus one, S1) while Fb is contemporaneously switched off; F1 is switched off and Fb is switched on for the ISI (the independent variable, taking four values per subject); Fb is switched off, and F2 on presenting the second stimulus card of the pair for 30 ms (stimulus two, S2); F2 is then switched off, Fb on and remains on. The segment of the stimulus presentation which contains the information on the

type of motion is again well within the latency of eye movements.

An experimental presentation is represented in figure 7.2 (not drawn to scale).

The independent variable was ISI. Each subject viewed stimulus presentations at four different ISIs (designated a, b, c and d since their actual values were set for each subject in pre experimental trials and depended on the threshold where the subject tended to change from "plane" to "space" responses). The subject's four ISIs increased by 10 ms steps, with a the shortest, b = a + 10 ms, c = a + 20 ms, and d = a + 30 ms. The dependent variable was the number of space or plane responses.

To eliminate overt verbal responses, the self centering two way switch was again used by the subject to communicate his decisions to the experimenter. Half the subjects were requested to move the switch up if they perceived the V as moving in space and down if it appeared to move in the plane, irrespective of the side on which motion occurred, or the direction of motion. The other half of the subjects (matched for sex and responding hand used first) moved the switch down if they perceived the shape as moving in space and up for motion in the plane.

Subjects were requested to respond space or plane to each stimulus presentation.

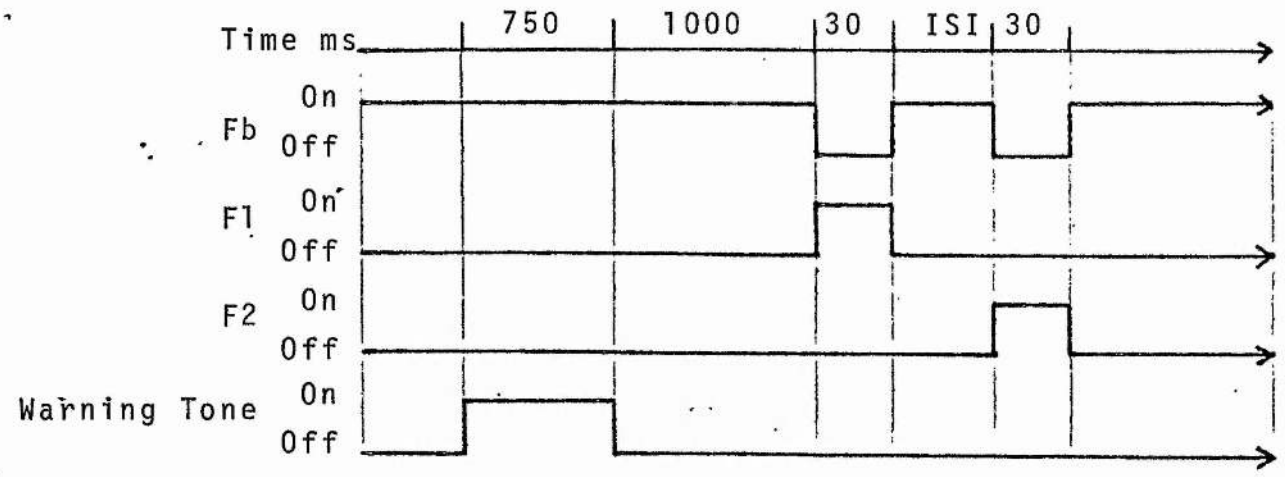


Figure 7.2

Experiment Five. The temporal sequence of events in an experimental presentation showing the on/off durations of the background field (Fb) and the stimulus fields (Fl and F2).

The movement of the switch, and hence the subject's response, was again communicated electronically to the experimenter.

All stimulus viewings were binocular.

In the previous experiments, a known (to the experimenter) direction of motion was presented and subjects were asked to report this direction. It was therefore possible to determine whether a response was correct or wrong. In this experiment, however, the report is based on the perceptual judgment of motion in the plane of the stimuli or rotation in the third dimension. Consequently a value of "correct" or "wrong" cannot be ascribed to responses in this experiment.

Pilot Studies

It was planned to present subjects with a range of stimulus conditions which would result in a shift of reported percept from "plane" to "space," and thus determine whether the cerebral hemispheres differed in the point on the stimulus continuum at which this change in percept occurred.

The literature indicated that the main parameters involved in determining whether a subject reported seeing motion in the plane of the stimuli or in the third dimension were the durations of the stimuli and ISI.

Prior to the experiment, therefore, pilot studies were conducted to confirm these findings, and choose suitable durations for the experimental variables, given the

constraint that the segment of the stimulus presentation which contains the information on the type of motion should be within the latency of eye movements (around 150 ms).

These pilot studies were conducted largely by the experimenter who triggered the tachistoscope and viewed the stimuli. On the basis of these observations, a set of parameters were selected and tested for their appropriateness on a number of assistants.

Clearly moving high contrast stimuli could be obtained by setting the % Intensity scale of Fb at min. and F1 = F2 (with the neutral density gelatin filters in place) at max.

It was found, confirming earlier workers and Kolers and Pomerantz (1971) that under stimulus conditions in which apparent motion is observed, i.e., excluding durations which result in the perception of simultaneity or sequentiality, for shorter total presentation times, i.e., S1 + ISI + S2, the perception tends to be of motion in the plane of the stimuli, while increasing this total presentation time increases the probability of perceiving rotation in the third dimension.

This effect held for increases in the duration of the stimuli; or increases in the ISI; or increases in the durations of the stimuli and the ISI, i.e., for any increases which result in an increase in the overall value of the sum S1 + ISI + S2. Note that here these effects were examined with S1 always equal to S2, and when the duration of S1 was increased, S2 was increased by the same

amount. Therefore, we have no information on the effect of increasing S1 alone (or S2 alone) while leaving the other two parameters constant, though we expect that, within limits, the S1 + ISI + S2 rule would also hold for independent increases of S1 or S2.

In this experiment, it was also necessary to present large numbers of stimulus trials to obtain statistically analyzable data. Therefore, minimizing the lag between successive trials is important in preventing fatigue, boredom or wandering attention in subjects. Since the ISI could be changed using one dial, it was proposed to use ISI as the independent variable rather than the durations of S1 and S2.

Experiments 3 and 4 had shown that with appropriate breaks subjects were able to cope with 160 presentations. Therefore, it was decided to use the same general experimental format and study four ISIs, designated a, b, c and d, which, to reduce inter trial dial changing, should increase in steps of 1 ms or 10 ms.

The pilot studies revealed that with the stimulus field durations set at 30 ms, the percept of motion would change from predominantly plane responses to predominantly space responses as the ISI was increased by 30 ms, i.e., for the min. ISI, a, the percept would be mainly of plastic deformations of the V in the plane, while for ISI, d, = a + 30 ms, the percepts of motion were mainly rotations in

depth. For ISI b = a + 10 ms, and ISI c = a + 20 ms, the proportion of "space" responses increased appropriately.

The values of a, b, c and d were set at whole tens of ms, e.g., 10, 20, 30 and 40 ms; or 30, 40, 50 and 60 ms, etc., and were individually set for each subject to span the range of ISIs where the change in percept from plane to space occurred. The maximum 'd' ISI set by any subject was 90 ms.

With the contrast set at that for the experiment, and S1 = S2 = 30 ms, the experimenter viewed the stimuli at a range of ISIs to examine the resultant percepts. The following describes these percepts, with additional notes where the reports of a subject or observer differed from that of the experimenter.

Under all conditions, the percept of motion (i.e., space or plane) was the same, irrespective of whether the V moved from V to Λ, or vice versa, except of course for the difference in direction.

ISI 'long' = 100 ms. A single V appears to move from its first position to an equally dark and distinct Λ in its final position by rotating in space about an axis formed by the points of contact of the two Vs presented as stimuli. The axis of rotation remained in the stimulus plane. To the experimenter, the spatial rotation always appeared in the third dimension with the apex of the V coming out of the stimulus plane towards him. Some subjects, however,

reported that the V rotated away from them through space behind the plane.

The superimposed Vs in the other visual field appear as a single stationary V on a twice flickering field.

The percept of rotation in space held for the experimenter for ISIs down to around 30 ms.

ISI 'medium' = 20 to 25 ms. A V appears to flick very quickly from its first to second position. There is a distinct perception of motion betwen the two positions, but no impression of rotation in space. The V seems to move to occupy its second position by traversing some path in the plane. Sometimes there is an impression of "phi" or pure objectless motion between the positions, but more frequently it seems as if the V folds, fixed at its two stationary end points, and hinges at its apex, to occupy its second position. Figure 7.3 attempts to illustrate this, the dashed lines representing a sample of the various positions apparently occupied by the V during its motion from its first to second position (all within the stimulus plane).

The superimposed Vs in the other visual field appear to be a stationary V flashed on once.

ISI 'short' = 1 ms. Some subjects perceived motion for ISIs down to 1 ms, with a few reporting rotations in space at this brief value. However, to others the percept at ISI = 1 ms was of a diamond flashed on (i.e., classical simultaneity) with the V presented in the second position,

i.e., S2, appearing darker. For some observers there was a sensation of motion (phi ?) from the lighter to the darker half of the diamond. To the experimenter, direct observation of the stimuli gave rise to the perception of motion in the plane, whereas with fixation on the spot, the stimuli appeared to be a diamond as described.

The superimposed Vs in the other visual field appeared as a single V flashed on once.

As the ISI was increased from 1 ms, there was a gradual change in the percept of the "moving" stimulus towards that described for 20-25 ms, with the probability of seeing clear motion in the plane increasing, i.e., for the same ISI between 1 and 20 ms, one might on some observations perceive a diamond with no associated motion and on others perceive a V hinging in the plane. Similarly, as the ISI was increased above 30 ms, the probability of plane percepts diminished while the probability of space responses increased.

The classical apparent motion continuum of simultaneity, motion, and sequentiality as ISI is increased, may therefore be observed with these stimuli, with the difference that during the motion segment, rotation in depth is perceived for longer ISIs.

Observers differ in the actual value of ISI at which this switch from "plane" to "space" percepts occurs. Thus, during the experiment proper, it was necessary to determine this threshold for each subject in pre trials.

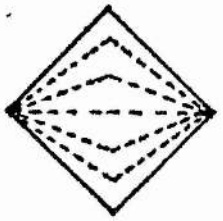


Figure 7.3

Experiment Five. Schematic diagram of the impression of "plane" motion. The V appears to fold into its second position occupying the dashed positions within the stimulus plane.

Field Checks

To ensure that stimuli with equal perceptual properties were being presented to each hemisphere, visual field checks were conducted prior to running the experiment.

Stimuli were presented in an order drawn from the sheets used in the experiment proper, with the assistant instructed to binocularly foveally fixate the appropriate visual field on each trial. Hence, as in previous visual field checks, hemisphere effects are eliminated and the fields are directly compared.

Stimuli were viewed at four ISIs which spanned each assistant's individual threshold of change from "plane" to "space" response.

There was no statistically significant difference between the visual fields in the ratio of space: plane responses, either overall (with a, b, c, d results pooled), or at any particular ISI (a, b, c, or d).

Therefore, it may be accepted that any differences between the hemispheres in the experimental proportion of space: plane responses, arises as a result of hemispheric differences and is not an artefact of the stimulus array.

Stimulus Presentations and Response Sheets

With four ISIs, two directions of motion, and two visual fields, the smallest set of stimulus presentations which will contain one of each stimulus configuration is 16 (4x2x2). This situation is identical to that of Experiment

3, and the same constraints and requirements which applied in that experiment are again relevant.

Consequently, here we only outline procedures that are discussed in detail in the corresponding section of Experiment 3.

Subjects responded to 160 balanced stimulus presentations, 80 to each cerebral hemisphere.

The response recording sheets listing the order of the stimulus presentations previously used in Experiments 3 and 4, were adapted for the recording of space or plane responses, otherwise they were identical. Again half the subjects, controlled for sex and hand used to respond first, received presentations from sheets with an inverse order of stimulus presentations.

Half of the 16 subjects, controlled for sex and response sheet began responding with their left hand, the other 8 began using their right hand. Eighty balanced trials were responded to with each hand, with hand changes and rest periods after 16, 32, 64, 96 and 128 responses. In the results section, presentations 1-32 are designated trial one; presentations 33-96, trial two; and presentations 97-160, trial 3.

During the running of the experiment, the data recorded were: the four ISIs set for each subject; the responding hand; the stimulus contrast (constant); and the response (whether space or plane) to each stimulus presentation.

Subjects

The 16 subjects were 8 adult males (mean age 16.5 yrs, max 17 yrs, min 16 yrs); and 8 adult females (mean age 16.4 yrs, max 17 yrs, min 16 yrs). All were right handed; see results section, and all had normal or corrected vision. All were pupils at Madras College St. Andrews, and had volunteered to participate in an experiment in visual perception.

Procedure with Subjects

Subjects were introduced to the experimental situation, informed about apparent motion, and were appraised of the experimental task in a manner similar to that reported fully in the corresponding section of Experiment 2. Therefore, only aspects of the procedure which differ are detailed here.

Binocular vision was again used.

The subject first viewed the stimulus cards in the tachistoscope with the fields switched on continuously, while it was explained that during the experiment, the upright and inverted Vs would be presented so that they appeared to move.

The subject was told that some observers reported seeing two types of motion, with the percept depending on the stimulus conditions. The V sometimes appeared to rotate, with its apex in space outside the stimulus plane, into its second position; and on other occasions, the motion appeared to be in the plane.

He was then asked to directly view a stimulus presentation and report whether he saw motion in space or in the plane.

Depending on the subject's report, the ISI was adjusted so as to increase the likelihood of a different motion percept for the next observation.

After the subject had directly viewed a number of presentations of both types of motion in both visual fields, he was asked to fixate on the spot and now communicate his responses to the experimenter via the two way switch, moving it up for "space" and down for "plane" (or conversely depending on the experimental condition). Moving the switch activated a display from which the experimenter could read the response. His task during the experiment would be for each stimulus presentation to communicate to the experimenter by means of the switch whether the V had moved in the plane or in space. He was not being asked to report the visual field in which the motion had occurred, or whether the V had moved up or down (i.e., from V to Λ or vice versa). He should make the best judgment of each presentation and respond, as trials would not be repeated. Presentations of space or plane motion would be interspersed. He should respond as quickly as possible but he should attempt to avoid errors caused by responding prior to the completion of the stimulus presentation. As he was responding by switch, there was no need to talk during the experiment; if, however, he

inadvertently moved the switch in the wrong direction, he could correct this verbally (errors of this nature were rare).

It was pointed out to the subject that motion occurred in only one visual field for each presentation. During the experiment, the side on which motion would occur would be randomly determined. He should not attempt to guess the side, or flick his eyes over to where motion had occurred. In order to obtain meaningful results in the experiment, it was necessary for him to be fixating the central spot during stimulus presentations. To help ensure that he was fixating on the spot at the correct time, he would hear a warning tone in the headphones one second prior to a stimulus presentation. When he heard this tone, he should fixate the spot. After responding, he could relax until he next heard the warning tone.

He would rest and change responding hand after each block of presentations, the experimenter would keep track of the hand to be used.

A series of trials were now run to select a set of four ISIs separated by 10 ms which would span a range in which responses would change from predominantly "plane" to predominantly "space." The subject now proceeded as in the experiment proper, receiving the warning tone, viewing the stimuli while fixating the spot, and responding using the swtich. The experimenter randomly presented stimuli in each visual field, and adjusted the ISI according to the

subject's responses. These trials served to set the subject's threshold, as practice trials for the experiment proper, and as a check on whether the subject was correctly following experimental instructions.

When the experimenter had determined the subject's threshold, he asked the subject to remove the headphones, and clarified any points in the procedure about which the subject was unsure.

The subject was then given a résumé of the procedure, e.g., the designated direction to move the switch for a space or plane response (irrespective of the side or direction of motion); the necessity of a prompt response; the hand to use first; and the importance of fixating the spot during stimulus presentations.

The experiment proper was then begun.

At the completion of data collection, the subject filled out the handedness questionnaire and was asked whether his responses had been mediated by sub vocal verbalization. He was thanked for his participation and given a full explanation of the hemispheric nature of the experiment, but cautioned not to discuss this with other subjects prior to their participation in the study.

Luminance Levels of the Stimulus Fields

A white card with a black central fixation spot was the fixation card in Fb, while white cards with upright or inverted Vs were the stimulus cards in F1 and F2.

The illumination levels of the stimuli were the same for all subjects in the experiment. The % Intensity scale for Fb was set at min., while the scales for F1 and F2, with the neutral density filters still in place, were set at max.

During the experiment, Fb is switched off while the stimulus fields are switched on, so measurements were taken accordingly.

The luminance levels of the fields were measured using an SEI photometer. These measurements were taken with the fields switched on continuously, and the levels presented below are the means of a number of readings taken at various points on the field (excluding the black fixation spot or stimulus line areas). There were no differences in the values obtained at different points in a field, or for the different stimulus cards.

	Values	
Field	% Intensity Setting	Luminance in log.ft.lamberts
Fb	min	0.25
F1 or F2	max	0.8

Results: Experiment Five

Prior to running the study, it was the experimenter's intuitive impression that some subjects might have difficulty in perceiving motion in space. However, much to his surprise, all subjects reported perceiving the Vs turning either in front of or behind the stimulus plane at the longer ISIs.

			Male		Female	
Hand	Hem.	ISI	Mean	SD	Mean	SD
L	L	a	37.50	44.32	25.00	26.73
L	L	b	87.50	23.15	43.75	17.68
L	L	c	81.25	25.88	62.50	23.15
L	L	d	75.00	26.73	87.50	23.15
L	R	a	31.25	25.88	50.00	46.29
L	R	b	62.50	35.36	31.25	37.20
L	R	c	56.25	17.68	75.00	26.73
L	R	d	75.00	37.80	62.50	44.32
R	L	a	43.75	32.04	43.75	32.04
R	L	b	68.75	37.20	75.00	26.73
R	L	c	68.75	37.20	87.50	23.15
R	L	d	75.00	26.73	75.00	37.80
R	R	a	37.50	44.32	25.00	26.73
R	R	b	43.75	32.04	68.75	45.81
R	R	c	62.50	51.75	56.25	32.04
R	R	d	75.00	37.80	50.00	37.80

Table 7A.

Experiment Five. Summary data. Percent Space responses Trial One across all subjects. Males (n = 8) and Females (n = 8). ISIs increase in 10ms steps.

			Male		Female	
Hand	Hem.	ISI	Mean	SD	Mean	SD
L	L	a	37.50	26.73	21.88	20.86
L	L	b	50.00	37.80	59.38	29.69
L	L	c	75.00	18.90	62.50	18.90
L	L	d	75.00	23.15	50.00	18.90
L	R	a	28.12	31.16	28.12	24.78
L	R	b	43.75	39.53	37.50	29.88
L	R	c	46.88	28.15	65.62	22.90
L	R	d	78.12	33.91	78.12	20.86
R	L	a	62.50	29.88	21.88	16.02
R	L	b	53.12	28.15	31.25	17.68
R	L	c	68.75	34.72	65.62	29.69
R	L	d	68.75	29.12	59.38	22.90
R	R	a	21.88	28.15	37.50	26.73
R	R	b	46.88	31.16	46.88	31.16
R	R	c	50.00	26.73	75.00	29.88
R	R	d	46.88	31.16	59.38	26.52

Table 7B.

Experiment Five. Summary data. Percent Space responses Trial Two across all subjects. Males (n = 8) and Females (n = 8). ISIs increase in 10ms steps.

			Male		Female	
Hand	Hem.	ISI	Mean	SD	Mean	SD
L	L	a	31.25	34.74	28.12	28.15
L	L	b	43.75	39.53	37.50	23.15
L	L	c	71.88	20.86	59.38	26.52
L	L	d	71.88	28.15	59.38	26.52
L	R	a	6.25	11.57	21.88	24.78
L	R	b	18.75	22.16	53.12	28.15
L	R	c	37.50	26.73	62.50	23.15
L	R	d	68.75	34.72	59.38	32.56
R	L	a	28.13	33.91	28.12	16.02
R	L	b	34.38	35.20	43.75	25.88
R	L	c	53.12	38.12	65.62	29.69
R	L	d	81.25	17.67	62,50	29.88
R	R	a	15.62	18.60	31.25	25.88
R	R	b	31.25	32.04	62.50	23.15
R	R	c	21.88	24.78	71.88	33.91
R	R	d	40.62	37.65	65.62	29.69

Table 7C.

Experiment Five. Percent space responses Trial Three. Summary data across all subjects. Males (n = 8) and Females (n = 8). ISIs increase in 10ms steps.

Indeed, the shortest ISI for some subjects had to be set at 1 ms to ensure sufficient "plane" responses.

No potential subject was eliminated from the experiment because of an inability to perceive both types of motion, or for any other reason.

Percent "space" responses were calculated for each hand/hemisphere/trial/condition combination for all subjects.

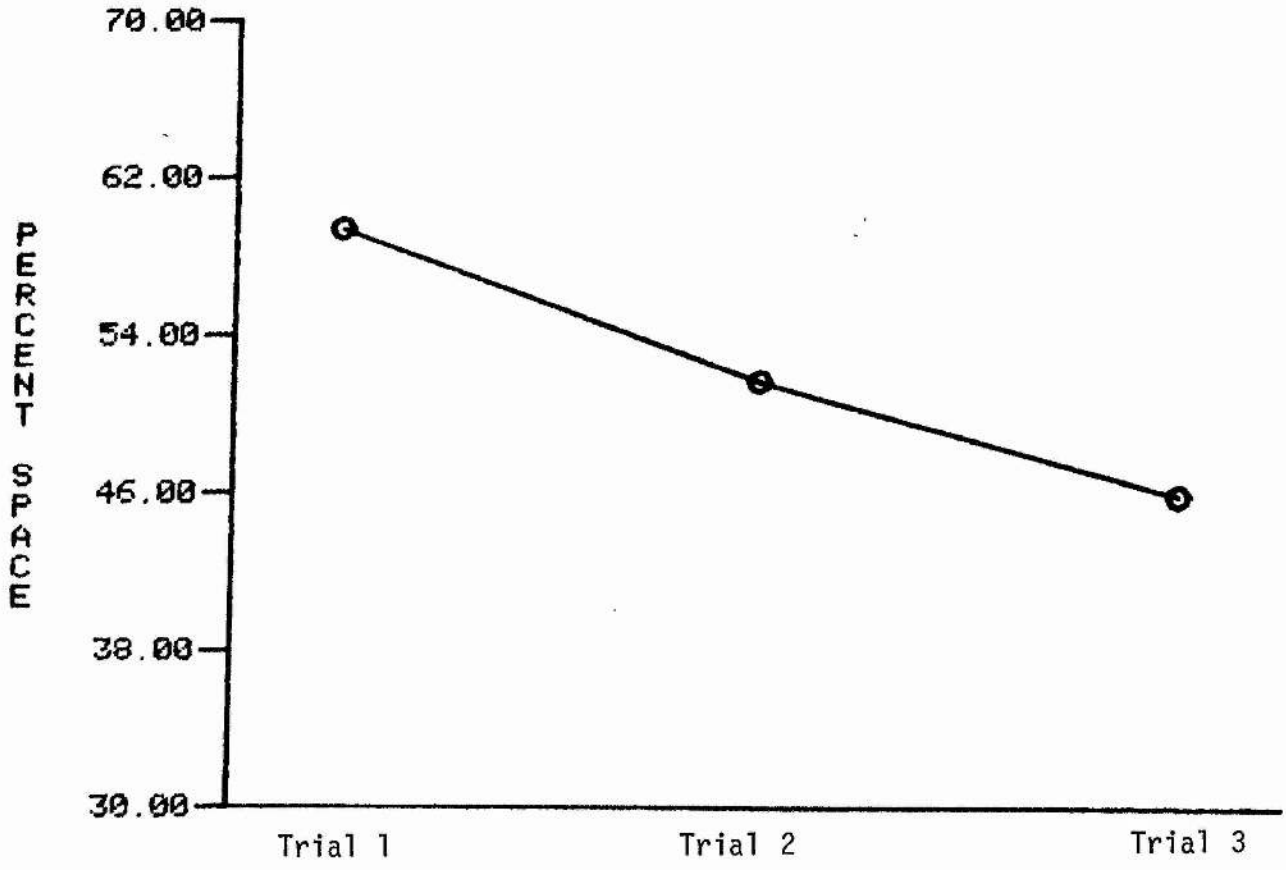
Analyses of variance were conducted on these data to test for statistically significant differences in the percentage of "space" responses. The within subject variables were hemisphere (left and right), hand (left and right), trial (one, two and three), and condition (four increasing inter stimulus intervals). The betweeen subject variable was sex (male and female).

The overall mean percent "space" response rate was 52.31%. Mean d ISI = 51.25 ms, SD = 19.28.

The significant main effects were trial, $p < .001$, table 7.3, Figure 7.4, which shows a linear fall in percent space responses with increasing trials; conditions, $p < .001$, table 7.4, Figure 7.5; the number of space responses increases as inter stimulus interval increases. Nonsignificant main effects: sex (male 51.89% space, female 52.73%) hand (left 52.34%, right 52.28%) or hemisphere (left 56.25%, right 48.37%).

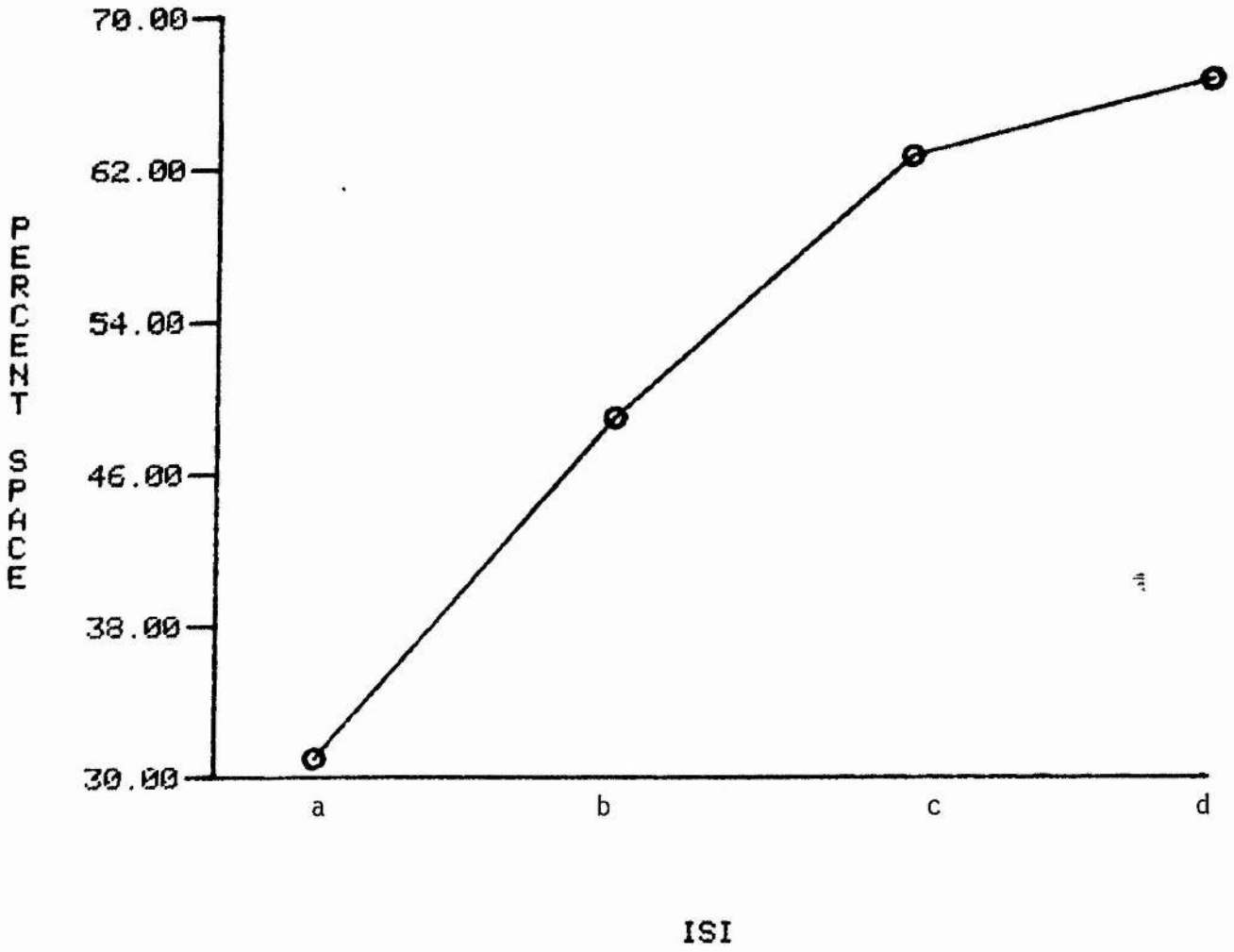
Significant first order effects were trial x sex, $p < .025$, Table 7.5, Figure 7.6, male percent space continues to fall linearly with increasing trials while female percent space responses level at 50% after trial one; hand x sex, $p < .05$, Table 7.6, Figure 7.7, males gave slightly fewer percent

FIGURE 7.4



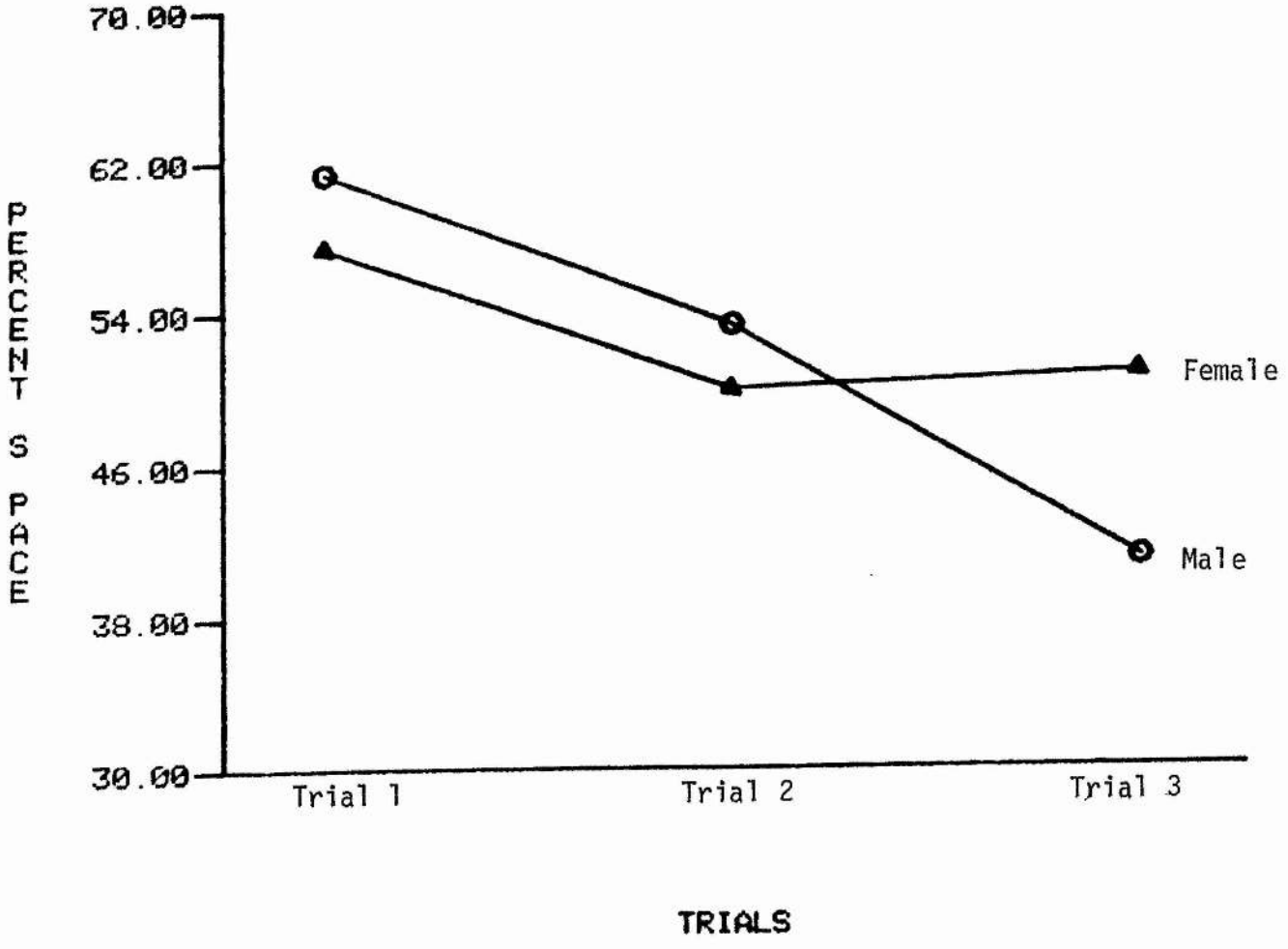
Experiment Five, apparently moving Vs. Fall in percent "space" responses over trials.

FIGURE 7.5



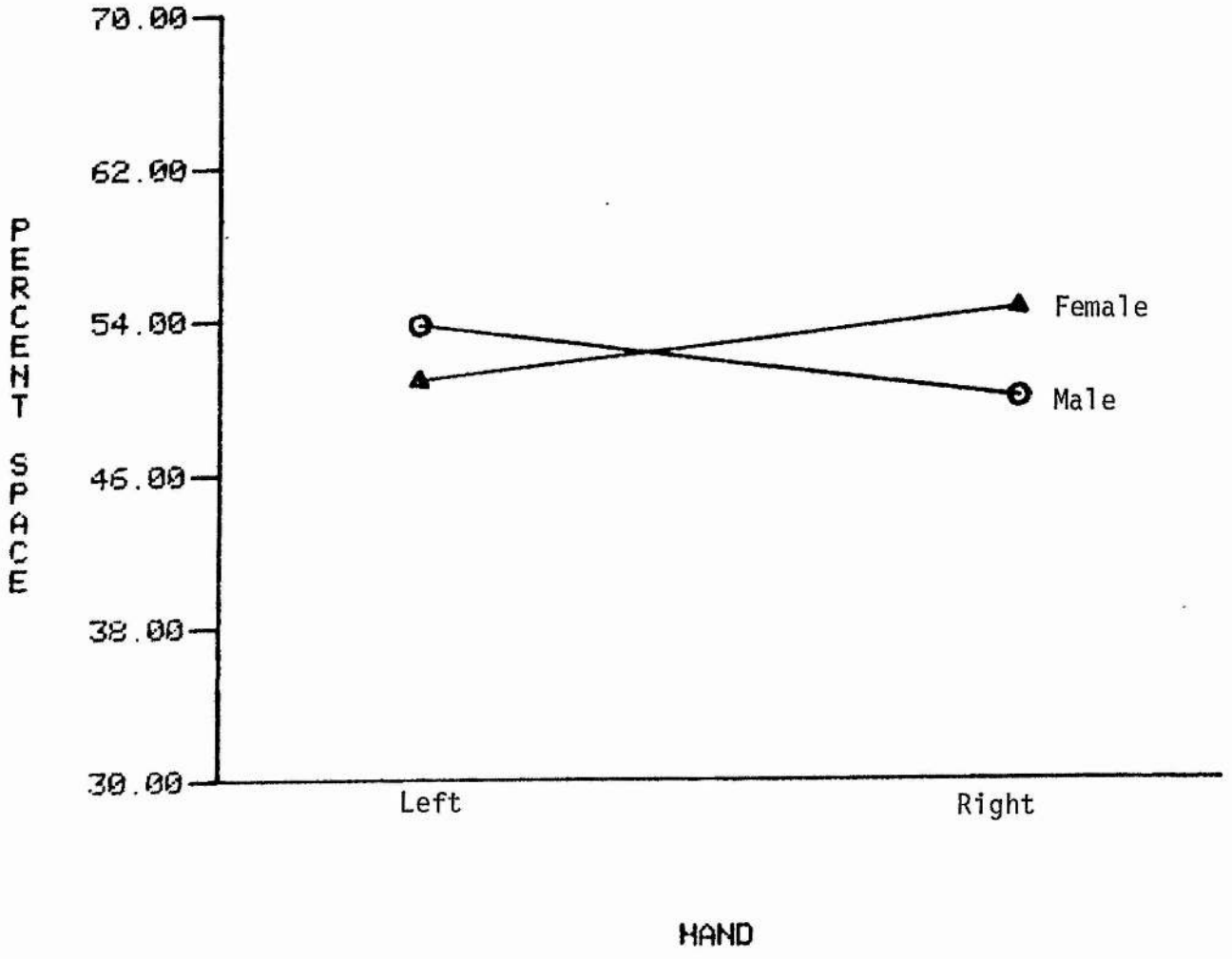
Experiment Five. Increase in percent "space" responses with increasing ISI.

FIGURE 7.6



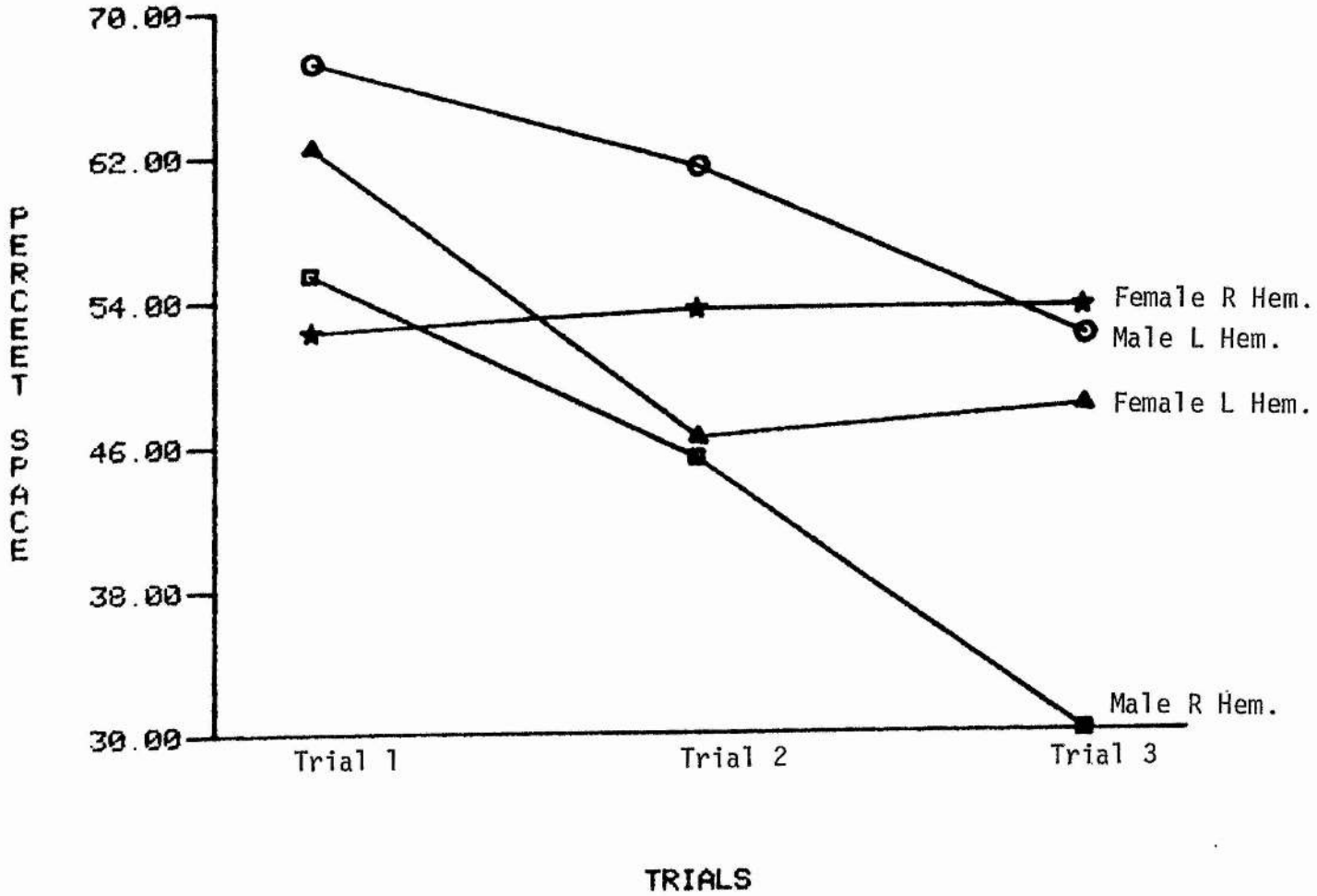
Experiment Five. Sex X Trials significant interaction.

FIGURE 7.7



Experiment Five. Sex X Hand interaction. The sexes are opposite in which hand gives more "space" responses.

FIGURE 7.8



Experiment Five. Hemisphere (contralateral VF) X Sex X Trials interaction. The corresponding hemispheres of the two sexes perform differently over trials. This difference is most marked for the right hemisphere.

space responses with their right hands while the converse is true for females. There were no additional significant first order effects.

The only significant triple interaction was trial x hemisphere x sex, $p < .005$, Table 7.7, Figure 7.8, for males, right hemisphere percent space responses were always fewer than left hemisphere percent space, and both rates decrease linearly with increasing trials; for females the right hemisphere percent space response level remains at around 50% across all three trials, while the rate for the left hemisphere falls to a constant level (approximately 47%) after trial one. A post hoc t test on the male left and right hemisphere percent space responses did not reach significance. t=2.17, df=7.

The mean right handedness score for males was 2.29 S.D. .41, for females 2.26, S.D. .32, overall mean = 2.27, S.D. .36.

The mean maximum ISI set by subjects was 51.25 ms. S.D. 19.28 ms.

The breakdown of reported sub-vocal verbalization usage was somewhat more complex than in previous experiments and is presented in table 7.8. Since the number of subjects in each cell is small and no main hemisphere effect was observed, no analyses were performed on these data.

TABLE 7.3

	Percent Space
Trial 1	59.37
Trial 2	51.66
Trial 3	45.90

	Percent Space
Condition 1	30.99
Condition 2	48.99
Condition 3	62.63
Condition 4	66.67

Table 7.4

	Percent Space	
	Male	Female
Trial 1	61.33	57.42
Trial 2	53.32	50.00
Trial 3	41.02	50.78

Table 7.5

	Percent Space	
	Left Hand	Right Hand
Male	53.78	50.00
Female	50.91	54.56

Table 7.6

		Percent Space	
		Left Hemisphere	Right Hemisphere
MALE	Trial 1	67.19	55.47
	Trial 2	61.33	45.31
	Trial 3	51.95	30.08
FEMALE	Trial 1	62.50	52.34
	Trial 2	46.48	53.52
	Trial 3	48.05	53.52

Table 7.7

	Male	Female
sub-vocal verbalization	1	4
no sub-vocal verbalization	3	2
no sub-vocal verbalization unless uncertain	1	0
sub-vocal verbalization until familiar with task	3	2

Table 7.8

Discussion

The experiment was conducted to examine whether there are differences between the cerebral hemispheres with respect to their decision processes regarding apparent motion in depth. V shaped stimuli which may be perceived as moving in the stimulus plane or in three dimensional space were presented over a range of ISIs. It was expected that as the ISI was increased, with all other stimulus parameters

remaining constant, percent "space" responses would increase relative to percent "plane" responses.

Figure 7.5 shows this expectation to be strongly confirmed ($p < .001$). As the ISI is increased from ISI a to ISI c, the increase in percent space responses is linear. The data point for ISI d suggests that percent space responses may be approaching an asymptote at around 70%. Percent space responses increase from 31% to 67% between ISI a and ISI d, with the 50% point close to ISI b. The increase in percent space responses with increasing ISI duration (or S1 + ISI + S2 duration) corroborates earlier work (Neuhaus, 1930; Kolers & Pomerantz, 1971).

However, the hand x sex intraction was not expected. Hand is merely being used to express the subject's decisions. In a right handed subject population, it is not clear why males gave slightly more space responses with their left hand while females gave more with their right, Figure 7.7. The result just reaches significance, $p = .044$, so is not a strong effect.

As trials increase, there is a linear fall in space responses, Figure 7.4. The labile nature of apparent motion percepts has long been documented. For example, DeSilva (1928) found that the likelihood of perceiving apparent motion and its quality were reduced by repeated observation. Interaction effects reveal that the current result depends on additional experimental variables. Figure 7.6 shows that the fall in percent space is observed between trials 1 and 2 for

both sexes but the fall between trials 2 and 3 only occurs for males (trials x sex, $p < .025$). Figure 7.8 reveals further differences. For males the fall over trials is parallel for both hemispheres with the left always giving more space responses for each trial. For females, percent space is constant over trials for the right hemisphere while the left falls to a constant level after trial 1 (trials x sex x hemisphere, $p < .005$). The most clear cut difference is observed in the right hemisphere response rate. For females, a constant standard appears to have been set for space responses which (unlike the male right hemisphere judgments) does not change over trials due to fatigue or learning.

A "space" response appears intuitively to be a more complex interpretation of the stimuli. The male right hemisphere mechanism which mediates decisions in the current experiment appears more likely to adapt over trials. This adaptation may be due to a faster rate of fatigue.

Alternately, assuming a learning effect, again intuitively it seems that "space" responses are less accurate decisions concerning the stimuli since the two Vs are presented in the plane; while the visual system interprets the motion as being in space. On this reasoning, the male right hemisphere (in contrast to the female right hemisphere) "learns" over trials that in fact there is nothing moving in the third dimension, and modifies its response accordingly.

If the depth mechanisms mediating the judgments studied in the experiment are the same as those for other types of

depth perception, one could further elucidate the above speculations. For example, using Julesz random texture stereograms, one could decide between practice or fatigue explanations depending on the outcome of a trials x sex x hemisphere analysis.

The clinical literature indicates that the right hemisphere tends to be more frequently the one injured when unilateral lesions result in upset depth perception. With normal subjects, Durnford and Kimura (1971) and Richards (1969) obtained conflicting hemisphere superiorities. Danta et al. (1978) tested left and right hemisphere lesioned patients on a bead dropping task (a depth judgment involving a moving target). Although a greater number of the right hemisphere group were impaired on this task, the difference was not statistically significant.

In the current experiment, we examined changes in the number of depth responses made by the two cerebral hemispheres to apparently moving stimuli as the ISI is increased. The lack of an overall hemisphere effect or an ISI x hemisphere interaction (despite a 36% increase in space responses over the four ISI conditions) suggest that the same mechanisms utilizing the same decision parameters are at work in both hemispheres.

However, the hemisphere x sex x trials interaction indicates that the hemispheres (especially the right) of male and female subjects do not continue to operate in a like manner when repeated observations are made of these stimuli.

CHAPTER 8

Experiment Six. Shapes in apparent motion.

Introduction

In Chapter One, we reviewed the clinical literature on brain injury which results in an inability to visually recognize objects, or a failure to perform geometrical or drawing tests due to visual detriments ("mind blindness," "visual spatial agnosia" et al.) (Jackson, 1976; Gowers, 1888; Macewen, 1893; Mills, 1898; Head, 1926; Nielsen, 1937; Paterson and Zangwill, 1944; McFie et al., 1950; Ettlinger et al., 1957; Piercy et al., 1960; McFie & Zangwill, 1960; Hecaen, 1969; DeAjurieguerra et al., 1960; Piercy & Smyth, 1962; Warrington et al., 1966). These reports indicate that such perceptual detriments are most frequently observed in cases of bilateral lesions. However, when they occur due to unilateral damage, the injured hemisphere is more often the right.

Patients with focal epilepsy of the right temporal lobe have more difficulty and take longer to interpret sketches than comparably injured left hemisphere patients (Milner, 1958). Kimura (1963) with similar patients, found that the right temporal group performed worse when dots or overlapping nonsense figures were tachistoscopically presented. Comparing left and right parietal lesioned patients on recognition of incomplete or

degraded figures, Warrington and James (1967) found the right parietal group to be worse.

With split brain patients, the dominance of the right hemisphere has been shown for geometric copying (Bogen & Gazzaniga, 1965); manual pointing to the match of a tachistoscopically presented chimeric figure (Levy et al., 1972); and tactual matching to a member of a visually presented geometric class (Franco & Sperry, 1977).

Despite these right hemisphere advantages, as was discussed in Chapter One, tachistoscopic studies of shape stimuli with normal subjects have not yielded consistent superiority for either hemisphere (Heron, 1957; Terrace, 1959; Bryden, 1960; Bryden & Rainey, 1963; Wyke & Ettlinger, 1961; Kimura, 1966; Kimura & Dunford, 1974; Beaumont & Dimond, 1975; White & White, 1975; Umilata et al., 1978; Hines, 1972, 1975, 1978; Goldberg et al., 1978).

The current experiment examines the possibility of hemispheric differences in the decision concerning what shape is moving. This is a more complex judgment than one on the direction of motion (examined in Experiments 1 to 4), since now detection of motion and a decision on what is moving are required.

Motion may be perceived in the absence of shape perception. In peripheral vision, motion may be detected but not the shape of the moving object. And Riddoch (1917) observed that in his brain injured cases, motion

perception may be retained with no clear percept of what is moving.

In the experiment to be reported, Julesz random texture patterns were again used. The shape to be detected is therefore concealed until the second card of the stimulus pair is displayed.

It was decided to study shapes which were geometrically similar (thus stimulating equal retinal areas) but perceptually different. For this purpose, squares and diamonds are suitable since a diamond may be produced simply by rotating a square through 45^{o}. The two shapes are distinct both perceptually and linguistically.

Random texture stimuli were also used in Experiments 2, 3 and 4. In Experiment 2, we observed a right hemisphere advantage attributed to the latter hemisphere's superior ability to process low contrast stimuli. While in Experiments 3 and 4, we found a left hemisphere advantage, accounted for in terms of a masking ISI. In the current experiment, we attempted to control for these more basic stimulus parameter effects which resulted in hemispheric differences. Thus we hoped to obtain an uncontaminated comparison of hemispheric decisions regarding moving shapes.

In Experiments 1 to 4, the subject's response was moving a switch in the direction of perceived motion. In this experiment, the same motor response was required with the subject required to move the switch up <u>or</u> down

depending on the shape perceived. Although a manual response is again required, the possibility of verbal mediation seems more likely (though is not necessary). Sub-vocal verbalization data were again collected.

Apparatus and Procedure

The experiment was conducted in the same room as Experiment 2, and utilized the same three field tachistoscope (with the neutral density gelatin filters in the stimulus fields), response switch, electronic response indicator, headphones and warning tone. These are fully described in the corresponding section of Experiment 2.

New stimulus cards, which when viewed in the appropriate sequence would result in the perception of a square or a diamond in motion, were constructed from enlarged photographs of a Julesz random dot stereogram. The properties of such stimuli are more completely discussed in the corresponding section of Experiment 2. The enlargement resulted in the items of texture being 1/14 in. x 1/14 in., or $.21^{o}$ x $.21^{o}$ VA when viewed in the tachistoscope.

As was noted in Experiment 2 regarding similar stimuli, very slight misalignments of sequentially presented cards produced perceptions of motion of the entire background. Prior to running each subject, stimulus cards had to be viewed under conditions of optimum motion and lined up carefully to eliminate swings of the background, and had to fit tightly into the cardholders so as to prevent misalignments when they were slid across between presentations. For this reason it was not possible to change cards between experimental presentations to a subject, as the backgrounds of cards

merely placed in the cardholders seldom lined up accurately. Therefore it was necessary to construct stimuli which, when viewed in the tachistoscope, would result in the perception of either a square or a diamond moving in either the left or right visual field, given a fixation field with one cardholder, and two stimulus fields each with two cardholders.

Consideration of the situation reveals that it is now necessary to have a randomly textured fixation card in Fb (as opposed to a white field as in earlier experiments), to define in the random dot texture of the four stimulus cards (choose one shape/visual field option for each card) either a square or a diamond in either the left or the right visual field, and move the texture items defining the shape relative to the corresponding texture area in Fb.

This is represented schematically in Figure 8.1. The shapes on the stimulus cards represent the areas of shifted texture. For illustrative purposes the displacements relative to the fixation spot are exaggerated. On the actual stimulus cards, the figures were displaced up by one texture item = 1/14 in., or .21^{o} VA in the tachistoscope. (This was the displacement also used in Experiments 2, 3, and 4.) All cards, including the fixation card, are now textured. The fixation spot only appeared on the fixation card, the dots in this

position on the stimulus cards in the figure are included as reference points.

Electronic Developments three field tachistoscopes are constructed such that the mirror image of the card placed in Fb is presented to the observer. It was therefore necessary to make the random dot pattern of the fixation card the mirror image of the pattern used for the stimulus cards.

The stimulus cards were constructed from four identically patterned 6 in. x 4-1/4 in. rectangles of the enlarged random dot stereogram.

Card 3 (a square in the right visual field) was made by defining a 1 in. square of texture with its centre on the same horizontal level as the central point of a 6 in. x 4-1/4 in. rectangle (equivalent to the fixation spot), and the midpoint of its nearest edge 1 in. horizontally to the right of this point. This defined square was then cut from an identical photograph and gummed securely onto the stimulus card, displaced upwards by one item of texture. Card 4 was similarly constructed by defining and moving the corresponding square in the LVF.

When viewed in the tachistoscope, the nearest edge of a square was 3^{o} VA from fixation, the furthest edge 6^{o} VA and its centre $4\text{-}1/2^{o}$ VA, to the left or right of fixation. These displacements are identical to those of the stimuli used in Experiments 2, 3, and 4.

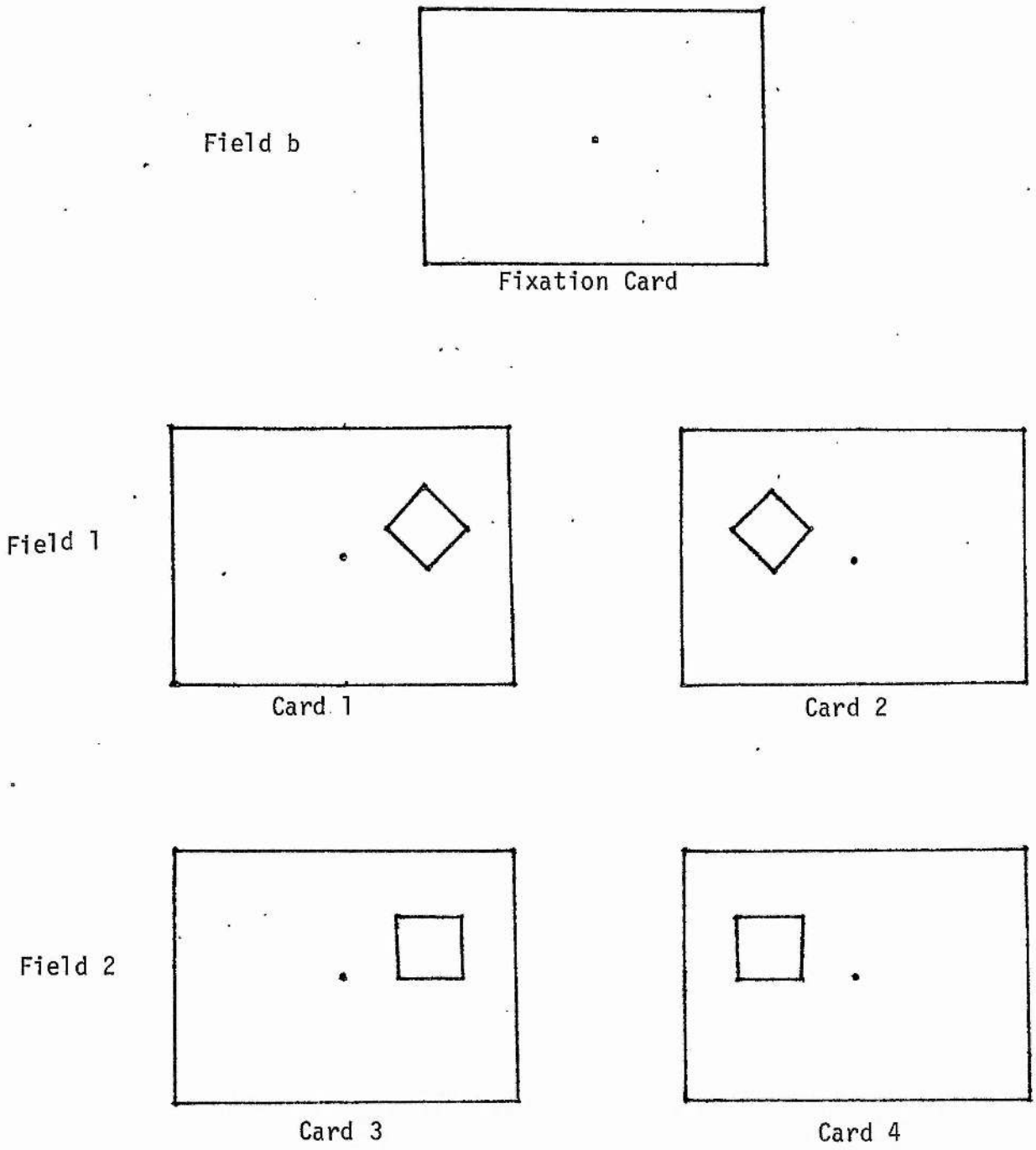


Figure 8.1

Experiment Six. Schematic diagram of experimental stimuli. During an experimental presentation, in a random texture field, a square or diamond appears to move in the left or right visual field. Field 1, 2 and b denote tachistoscope field.

The purpose of using random dot stimuli is, until the presentation of the second card of a pair, to prevent the subject from determining in which visual field the moving stimulus will appear. Therefore, one cannot construct stimulus cards for diamonds simply by cutting diagonally across square items of texture and moving the shape, as the edges produced would reveal the diamond when the card is presented alone. In addition, detecting a diagonal across an item of texture during the presentation of motion would cue the subject as to diamonds. "Diamond" stimulus cards were therefore prepared by cutting stepwise up the items of texture to produce "diamonds" of side approximately equal to 1 in. Figure 8.2 presents a square and a diamond, actual size.

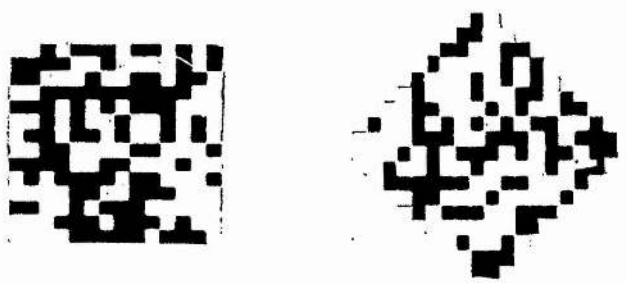


Figure 8.2

The shapes which appear to move in the textured background

Note that the apexes of the diamond are two items of texture wide and the steps are one item of texture. The reason for using diamonds with blunt apexes was to produce shapes, approximately the same area as the squares, which did not protrude too much towards fixation when their

centres were placed in the same position as the centres of the squares. The diamond stimulus cards were produced by locating in the 6 in. x 4-1/4 in. random texture the position equivalent to the centre of the 1 in. stimulus square in the appropriate visual field, and defining the diamond with this point as its centre. Diamonds, like the squares, were cut from identical photographs, displaced up by 1 item of texture, and pasted onto the stimulus cards to produce cards 1 and 2.

Due to the stepwise cutting process, the area of a diamond was slightly less than that of a square, being 180 items of texture rather than 196. Despite this slight decrease in area, the "points" of a diamond protruded two items of texture outside the boundaries of a square. Consequently the innermost points of the diamonds were 0.4^{o} VA closer to the fixation spot than were the nearest edges of the squares. Similarly their outermost points were 0.4^{o} VA further from fixation than were the outer edges of the squares. Thus, the nearest point of a diamond was 2.6^{o} VA from fixation, the furtherest point 6.4^{o} vA, while the centre like that of a square, was 4.5^{o} VA. Note that even the nearest point is sufficiently displaced from fixation to ensure hemispheric lateralization when a subject is binocularly fixating the spot.

Slight imperfections at the edges of the squares or diamonds were painted out using black or white poster

paint and the resultant 6 in. x 4-1/4 in. patterns and the mirror image for Fb were copied on a Fordigraph 9F/3 photocopier to produce stimuli with no raised areas. The stimulus cards were completed by gumming the copied patterns onto 6 in. x 4-1/4 in. thin rigid cardboard. A copy of the stimuli appears in Appendix B. The photocopying process results in stimuli of slightly lower contrast than those used in Experiments 2, 3 and 4.

In the tachistoscope, when Fb is switched on simultaneously with, for example, Fl containing card 1, all items of texture superimpose except for the diamond in the RVF, which is displaced upwards. Analogous superimpositions and displacements occur for Fb and the other stimulus cards.

Since Fb now contained a random dot card rather than a white field, it was not possible to switch back to Fb during the field presentation sequence to use Fb as an ISI, as in Experiments 3 and 4. Similarly, it was not possible to use Fb as a white background for the stimulus cards to manipulate the stimulus contrast as in Experiment 2. However, since hemispheric differences were observed in these experiments which resulted from using such experimental conditions, this loss of Fb as a background or ISI field is no disadvantage. We wished to study the hemispheric response to moving shapes uncontaminated by stimulus parameters already shown to produce hemispheric differences.

It was therefore decided to manipulate the duration of the stimulus fields as the experimental independent variable. The contrast of the patterns is not attenuated by a white background, and there is no ISI between stimuli.

Switching from the patterned field in Fb to e.g. card 1 in F1, and back to Fb, produces for suitable durations of F1, the percept of a diamond moving quickly up then down in the right visual field. Analogously when the field in Fb is switched with card 3 in F2, a square appears to move up then down in the RVF. Similarly for cards 2 and 4. That is:

Field	Card Presented	Shape	Visual Field	Motion
1	1	diamond	right	up/down
1	2	diamond	left	up/down
2	3	square	right	up/down
2	4	square	left	up/down

Table 8.1

Note that in this experiment, on a particular stimulus presentation, the switches are between Fb and F1; or between Fb and F2.

For each experimental presentation, motion of one shape (square or diamond) occurs in only one visual field (left or right).

To control for any properties of the stimuli which might have favored shape detection in one visual field, half of the subjects, matched for sex and the hand first

used to respond, viewed the cards rotated through 180° and replaced in the same cardholder. For all cards, this reverses the visual field of the moving stimulus and the nature of the motion, which becomes down/up (cf. table 8.1).

Pilot Studies

The stimuli were viewed binocularly under a range of conditions in order to choose a set of parameters which would result in approximately 75% correct identification, in a forced choice situation, of which shape is moving. Again, a range of experimental values were to be used to examine whether one hemisphere begins to correctly identify the shape at shorter stimulus durations than its counterpart.

As with the pilot studies for previous experiments, the parameters initially derived by the experimenter were verified and finalized by the observations of assistants.

It was found that the step in stimulus field duration between being unable to identify the moving shape and being 100% correct, was very brief.

It was found that four values of stimulus field duration (a, b, c and d, empirically between 10 and 20 ms), separated by increments of 2 ms, resulted in too great an increment for most observers, i.e., at duration a, results might be at chance, whereas at duration d = a + 6 ms, reports were approximately 100% correct, with

empirically interesting data only derived from durations b and c.

Increments of 1 ms gave more linear data and were therefore used, with d = a + 3 ms, although using these values perhaps resulted in a somewhat curtailed range.

Since Fb now contained a patterned field contributing to the percept of motion, its luminance level was set equal to that of the other two fields. Observations in the pilot studies indicated that a luminance level of 0.5 log.ft. lamberts in all fields resulted in suitable apparent brightness levels of the stimuli, and produced the required rate of correct responses. During the experiment, this luminance level was constant for all subjects.

Direct observation of the moving stimuli resulted in correct identification of which shape was moving at briefer stimulus durations than did fixation on the spot. However, the subjective impression was similar irrespective of fixation point. Thus, for fixation on the spot and with the cards orientated as for part one of the experiment (i.e., as depicted in figure 8.1), the percept for longer stimulus field durations was of say a diamond jumping up then quickly down again in the LVF. For presentations of the same stimulus at a shorter duration, the percept would be of a brief up then down motion in the LVF, but with no clear impression of the shape. Thus, as

would be expected, the percept of motion remains for briefer durations than does the percept of what is moving.

Apparatus and Procedure Continued

The .75 sec, 1 kh tone again warned subjects that a presentation was due.

Fb, with the random dot texture fixation card remains on throughout experimental presentations except during F1 or F2.

The sequence for an experimental presentation was as follows: the subject receives the warning tone and fixates the central spot on Fb; 1 sec after the tone, Fb is switched off contemporaneously with F1 or F2 being switched on; F1 or F2 remains on for one of four durations (set to each subject's individual threshold); F1 or F2 is switched off and Fb is switched on contemporaneously and remains on.

The subject responds.

The duration of the stimulus field, which contains the information about which shape is moving, was set for subjects in the experiment at between 10 and 20 ms, well within the latency of eye movements.

An experimental presentation is represented in figure 8.3 (not drawn to scale).

Subjects again conveyed their responses nonverbally to the experimenter via the two way switch. Half the subjects, controlled for sex and hand first used to respond, were requested to move the switch down if they

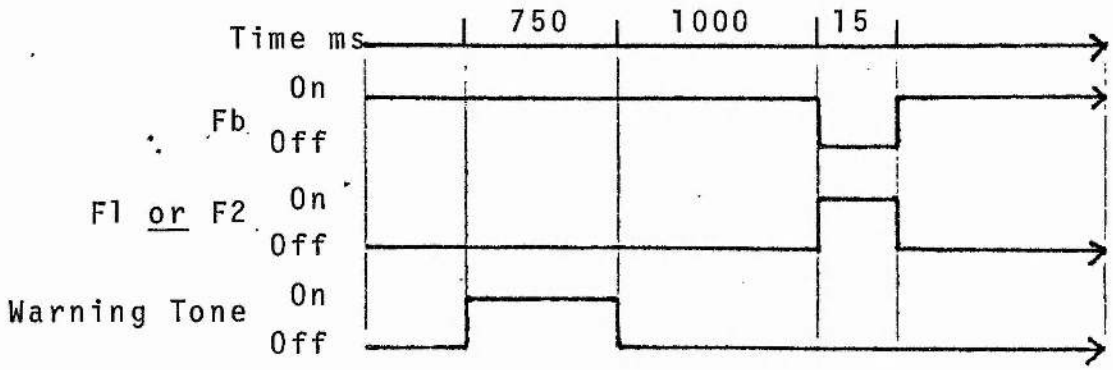


Figure 8.3

Experiment Six. Temporal sequence of events during an experimental presentation showing the on/off durations of the background field (Fb) and the stimulus fields (F1 or F2).

saw a square move, and up if a diamond. For the other half of the subjects, the converse response was required. Subjects reported the shape in motion, irrespective of the visual field where motion occurred or the type of motion perceived. The subject's response was again communicated to an electronic display from which the experimenter could read the subject's response.

Subjects were obliged to respond to each stimulus presentation which was made only once (a forced choice paradigm was employed).

As in previous experiments, subjects received no feedback as to the correctness of individual responses.

Field Checks

To ensure that the shapes were equally detectable in both visual fields, the stimuli were observed binocularly as in the experiment proper, but for these checks the moving stimuli were foveally fixated, thus eliminating hemispheric effects.

The stimuli were presented at four stimulus field durations separated by 1 ms around the assistants' 75% correct level for direct observation. The presentations were made in each visual field according to the schedule for the experiment, with the assistant instructed prior to each observation as to in which field the motion would occur.

There were no statistically significant differences between the fields for the overall number of errors made during these observations. LVF 81% correct RVF 78%, t=0.4.

Therefore it may be accepted that if any hemispheric differences appear, they arise as a result of differential capacities of the cerebral hemispheres and are not an artefact of the stimulus array.

Stimulus Presentations and Response Sheets

The independent measure was the duration of the stimulus field, which was assigned four values, designated a, b, c and d, depending on the subject's individual threshold.

Thus, with four stimulus field durations, two shapes to be differentiated, and two visual fields, as fully discussed in the corresponding section of Experiment 3, the smallest number of presentations which will contain one of each stimulus configuration is 16. (Points detailed in Experiment 3 are only outlined here.)

Subjects responded to 160 balanced stimulus presentations, 80 to each cerebral hemisphere.

The stimulus presentation order and response recording sheets used in Experiment 3 were adapted for use in this experiment, with direction of motion changed to shape, and a column included to record the subjects' report of this.

To control for any order effects, half the subjects, matched for sex and hand first used to respond, received

presentations from sheets with an inverse order of stimulus conditions.

Half of the 16 subjects, balanced for sex and response sheet, began responding with their left hand, the other 8 began by using their right hand. Eighty balanced trials were responded to with each hand, with hand changes and rest periods after 16, 32, 64, 96, and 128 responses.

During the running of the experiment, the data recorded were: the four stimulus field durations set for each subject; the responding hand; the luminance levels of the stimulus fields (constant for all subjects); and response (whether square or diamond) to each stimulus presentation.

As in Experiments 3, 4 and 5, in the results section, trial 1 = presentations 1-32; trial 2 = presentations 33-96; and trial 3 = presentations 97-160.

Subjects

The 16 subjects were 8 adult males (mean age 20.75 yrs., max. 24 yrs., min. 19 yrs.); and 8 adult females (mean age 20.75 yrs., max. 24 yrs., min. 17 yrs.). Seven of the males were undergraduate students, one a post-graduate student, all at St. Andrews University. Six of the females were undergraduate students, four at St. Andrews University, and two at Glasgow University, one subject was a teacher and the other a secretary.

All subjects were right handed, see results section, and all had normal or corrected vision. They had

volunteered to participate in an experiment on visual perception.

Luminance Levels of the Stimulus Fields

For all subjects, the % Intensity scales of the optical unit of the tachistoscope for F1 and F2 were set at 45 (with the neutrol density gelatin filters in place) and Fb set at 15.

Note that during the experiment, no two fields are on simultaneously. Fields were switched on continuously and their luminances measured using the SEI photometer. Measurements were taken at white items of texture.

The values presented are the means of a number of photometer readings taken at different points on the stimulus fields. There were no differences in the readings at different points on a stimulus field, or for the different stimulus cards.

Field	% Intensity Setting	Luminance log.ft. lamberts
Fb	15	0.5
F1	45	0.5
F2	45	0.5

Table 8.2

Procedure with Subjects

Subjects were introduced to the experimental situation, had apparent motion explained and were appraised of their task in a fashion similar to that reported fully in the corresponding section of Experiment 2. Therefore, only aspects of the procedure which differ will be elaborated here.

The subject viewed the stimuli binocularly throughout the experiment.

While the subject examined the random dot fixation field, he was told that during experimental presentations, an area of texture defining either a square or a diamond would appear to move in either the left or right visual field.

He was then shown the four moving stimulus configurations. For these presentations he was asked to look directly at the stimuli and familiarize himself with them. The duration of the stimulus field for these observations was 150 ms which made the shapes stand out clearly.

It was explained to the subject that his experimental task was to detect which shape was presented irrespective of the visual field or type of motion, and communicate this to the experimenter via the switch. He should move the switch up for diamonds and down for squares (or conversely depending on his experimental group) as quickly as possible, but he should try to avoid responding prior

to the stimulus presentation as number correct was the primary measure. During the experiment, trials would not be repeated, so if unsure of the shape presented, he should guess on the basis of what he had seen. As he was responding by switch, there was no need to talk, but if he moved the switch in the wrong direction by mistake, he could change his response verbally.

He would be presented with shapes randomly in each visual field, with only one shape in one visual field per trial.

The importance of fixating the spot during stimulus presentations was emphasized, and he should avoid trying to anticipate the visual field in which the stimulus would appear, and not flick his eyes over to where it had occurred. He would receive a warning tone one second prior to each stimulus presentation, when he heard this, he should fixate the spot until completion of the stimulus cycle.

During the experiment, the stimulus duration would be such that he would sometimes make mistakes about the shape presented.

The threshold setting pretrials were conducted with the subject receiving the warning tone through the headphones, fixating the spot, and responding via the switch.

Presentations of shape/side were made randomly and the stimulus field durations were quickly reduced to 30

ms, where the shapes are still detected with relative ease. Decreases of 5 ms were made for each subsequent presentation until the subject made an error or hesitated considerably in his response. When this occurred, always with the stimulus duration in the 10 to 20 ms range, more presentations varying by 1 ms were made to more accurately ascertain the subject's threshold. When this had been determined, four stimulus field durations separated by 1 ms were selected for use in the experiment, and checked by further presentations.

These pretrials also served as practice for the subject, and confirmation to the experimenter that the subject was following experimental instructions.

The subject then removed the headphones and any problems were clarified.

He was told that during the experiment he would randomly receive presentations at different stimulus durations so he should not be surprised if, on some trials, the shape appeared less distinct.

He would be given breaks during the experiment and at these breaks change responding hand. The experimenter would keep track of this.

The subject was then given a resume of the experimental sequence--the tone would warn him to fixate the spot; the presentation would follow in one second and he should respond according to shape, up for diamonds, down for squares (or conversely) and guess if uncertain,

irrespective of the visual field or the type of motion perceived; after responding he could relax till the tone occurred again. He was reminded of the hand to use first and the importance of fixating the spot.

The experiment proceeded.

At the completion of the experiment, the subject filled out the handedness questionnaire; was asked about response mediation by sub vocal verbalization; had the purpose of the experiment fully explained; was asked to recruit friends as subjects but not to reveal the hemispheric nature of the task to them prior to their participation; and thanked for his assistance; all as in previous experiments.

Results: Experiment Six

No subject was unable to correctly identify squares and diamonds at the appropriate stimulus field durations. No one who volunteered to participate in the experiment was eliminated for an inability to perceive the shapes at significantly above chance levels, or for any other reason.

Percent correct scores were calculated for each hand/hemisphere/trial/ condition/shape combination for all 16 subjects.

Analyses of variance were performed on the percent correct scores to test for statistically significant effects. The within subject variables were hemisphere (left and right), hand (left and right), trial (one, two

			Male		Female	
Hem.	Cond.	Shape	Mean	SD	Mean	SD
L	a	S	87.50	35.36	87.50	35.36
L	a	D	62.50	51.75	37.50	51.75
L	b	S	87.50	35.36	75.00	46.29
L	b	D	87.50	35.36	62.50	51.75
L	c	S	75.00	46.29	100.00	00.00
L	c	D	87.50	35.35	75.00	46.29
L	d	S	62.50	51.75	100.00	00.00
L	d	D	87.50	35.36	37.50	51.75
R	a	S	75.00	46.29	100.00	00.00
R	a	D	37.50	51.75	62.50	51.75
R	b	S	100.00	00.00	75.00	46.29
R	b	D	50.00	53.45	62.50	51.75
R	c	S	100.00	00.00	87.50	35.35
R	c	D	87.50	35.35	87.50	35.35
R	d	S	100.00	00.00	100.00	00.00
R	d	D	37.50	51.75	62.50	51.75

Table 8A.

Experiment Six. Summary data. Percent correct Trial One, Left Hand across all subjects. Males (n = 8) and Females (n = 8). The conditions are increasing stimulus field durations. S = square; D = diamond.

			Male		Female	
Hem.	Cond.	Shape	Mean	SD	Mean	SD
L	a	S	75.00	46.29	100.00	00.00
L	a	D	62.50	51.75	87.50	35.35
L	b	S	87.50	35.36	87.50	35.35
L	b	D	100.00	00.00	50.00	53.45
L	c	S	75.00	46.29	75.00	46.29
L	c	D	75.00	46.29	75.00	46.29
L	d	S	100.00	00.00	75.00	46.29
L	d	D	62.50	51.75	62.50	51.75
R	a	S	100.00	00.00	75.00	46.29
R	a	D	62.50	51.75	50.00	53.45
R	b	S	100.00	00.00	87.50	35.35
R	b	D	62.50	51.75	62.50	51.75
R	c	S	100.00	00.00	75.00	46.29
R	c	D	75.00	46.29	75.00	46.29
R	d	S	100.00	00.00	100.00	00.00
R	d	D	87.50	35.35	75.00	46.29

Table 8B.

Experiment Six. Summary data. Percent correct Trial One, Right Hand across all subjects. Males (n = 8) and Females (n = 8).

The conditions are increasing stimulus field durations.

S = square; D = diamond.

			Male		Female	
Hem.	Cond.	Shape	Mean	SD	Mean	SD
L	a	S	87.50	35.36	87.50	23.15
L	a	D	81.25	25.88	68.75	37.20
L	b	S	93.75	17.68	93.75	17.68
L	b	D	93.75	17.68	75.00	37.80
L	c	S	100.00	00.00	100.00	00.00
L	c	D	87.50	23.15	68.75	45.80
L	d	S	81.25	37.20	93.75	17.68
L	d	D	68.75	45.81	62.50	35.36
R	a	S	100.00	00.00	87.50	23.15
R	a	D	68.75	25.88	75.00	37.80
R	b	S	87.50	23.15	93.75	17.68
R	b	D	56.25	32.04	68.75	25.88
R	c	S	100.00	00.00	93.75	17.68
R	c	D	75.00	37.80	81.25	37.20
R	d	S	100.00	00.00	68.75	37.20
R	d	D	75.00	26.73	81.25	37.20

Table 8C.

Experiment Six. Summary data. Percent correct Trial Two, Left hand across all subjects. Males (n = 8) and Females (n = 8). The conditions are increasing stimulus field durations. S = square; D = diamond.

			Male		Female	
Hem.	Cond.	Shape	Mean	SD	Mean	SD
L	a	S	87.50	23.15	87.50	23.15
L	a	D	68.75	37.20	56.25	49.55
L	b	S	81.25	37.20	87.50	23.15
L	b	D	87.50	23.15	68.75	25.88
L	c	S	81.25	25.88	93.75	17.68
L	c	D	81.25	25.88	62.50	44.32
L	d	S	87.50	35.36	93.75	17.68
L	d	D	87.50	23.15	56.25	32.04
R	a	S	93.75	17.68	100.00	00.00
R	a	D	81.25	25.88	75.00	37.80
R	b	S	93.75	17.68	93.75	17.68
R	b	D	62.50	35.36	87.50	23.15
R	c	S	100.00	00.00	93.75	17.68
R	c	D	68.75	37.20	62.50	35.36
R	d	S	100.00	00.00	81.25	37.20
R	d	D	62.50	35.36	81.25	25.88

Table 8D.

Experiment Six. Summary data. Percent correct Trial Two. Right Hand across all subjects. Males (n = 8) and Females (n = 8).

The conditions are increasing stimulus field durations.

S = square; D = diamond.

			Male		Female	
Hem.	Cond.	shape	Mean	SD	Mean	SD
L	a	S	68.75	45.81	81.25	37.20
L	a	D	68.75	37.20	75.00	26.73
L	b	S	75.00	46.29	81.25	25.88
L	b	D	93.75	17.68	62.50	51.75
L	c	S	87.50	23.15	100.00	00.00
L	c	D	87.50	23.15	62.50	44.32
L	d	S	87.50	23.15	93.75	17.68
L	d	D	87.50	35.36	75.00	37.80
R	a	S	93.75	17.67	100.00	00.00
R	a	D	62.50	44.32	75.00	26.73
R	b	S	87.50	23.15	93.75	17.68
R	b	D	50.00	46.29	68.75	37.20
R	c	S	100.00	00.00	93.75	17.68
R	c	D	68.75	45.81	100.00	00.00
R	d	S	100.00	00.00	87.50	23.14
R	d	D	75.00	37.80	62.50	23.14

Table 8E.

Experiment Six. summary data. Percent correct Trial Three, Left Hand across all subjects. Males (n = 8) and Females (n = 8).

The conditions are increasing stumulus field durations.

S = square; D = diamond.

			Male		Female	
Hem.	Cond.	Shape	Mean	SD	Mean	SD
L	a	S	87.50	23.15	93.75	17.68
L	a	D	62,50	44.32	62.50	35.36
L	b	S	93.75	17.68	93.75	17.68
L	b	D	75.00	26.73	62.50	35.36
L	c	S	87.50	23.15	81.25	25.88
L	c	D	68.75	45.81	68.75	37.20
L	d	S	81.25	37.20	93.75	17.68
L	d	D	68.75	37.20	75.00	37.79
R	a	S	100.00	00.00	87.50	23.15
R	a	D	75.00	37.80	75.00	26.73
R	b	S	87.50	23.15	87.50	23.15
R	b	D	68.75	45.81	75.00	37.80
R	c	S	100.00	00.00	93.75	17.68
R	c	D	87.50	23.15	81.25	25.88
R	d	S	100.00	00.00	93.75	17.68
R	d	D	68.75	37.20	93.75	17.68

Table 8F.

Experiment Six. Summary data. Percent correct Trial Three Right Hand across all subjects. Males (n = 8) and Females (n = 8). The conditions are increasing stimulus field durations. S = square; D = diamond.

and three), condition (four increasing stimulus field durations), and shape (squares and diamonds). The between subject variable was sex (male and female).

The mean minimum field duration set by subjects was 13.0 ms, standard deviation 3.4 ms.

The mean overall percent correct score was 80.60%.

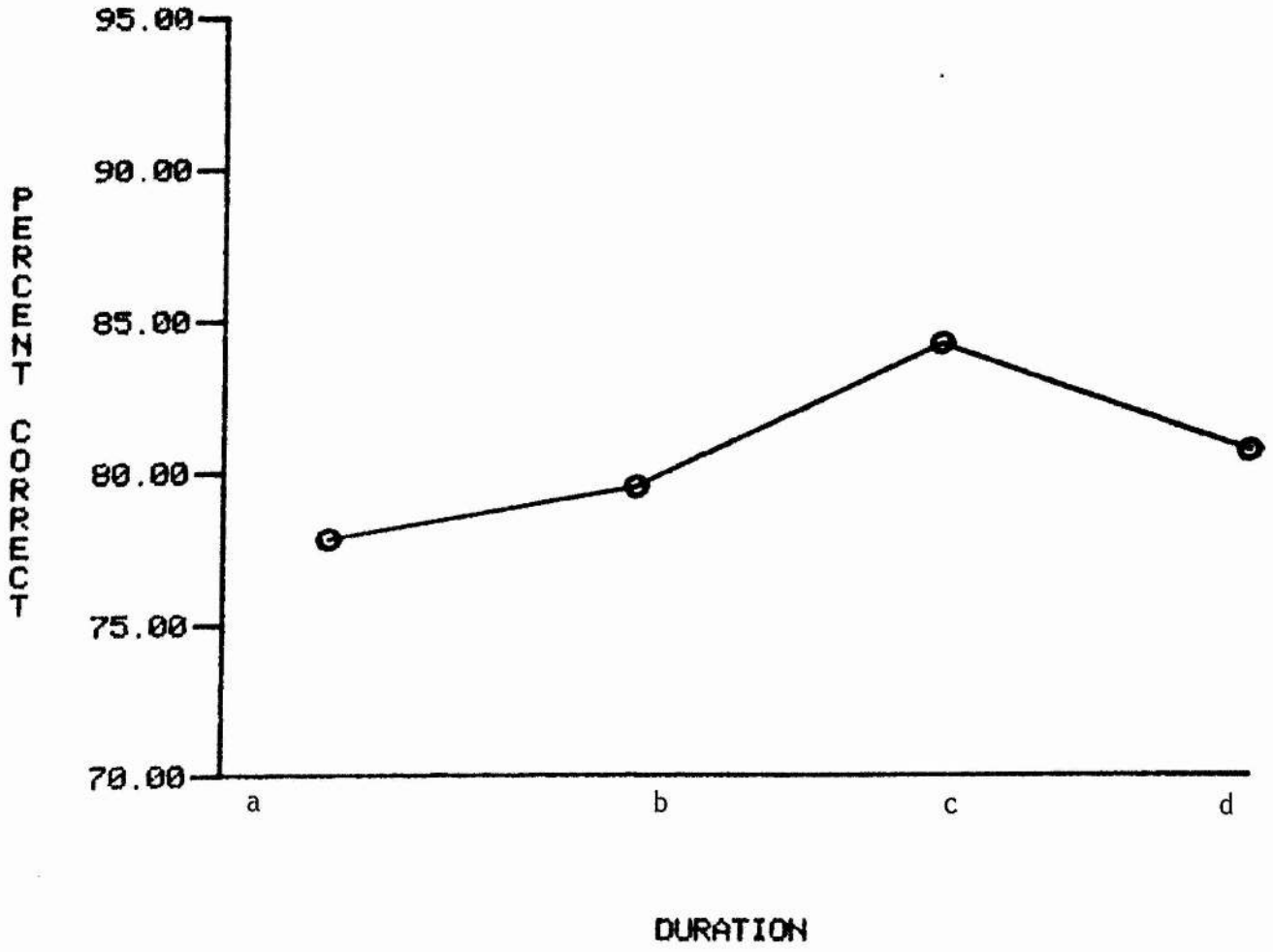
The significant main effects were: condition, $p < .05$, table 8.3, figure 8.4, percent correct increases with increasing stimulus field duration, with a maximum occurring at condition 3; shape, $p < .001$, subjects scored 90.04 percent correct for squares and 71.16% for diamonds. Non significant effects: sex (male 81.64% female 79.56%) trial (one 77.73% two 82.23% three 81.84%) hand (left 80.21% right 80.99%) or hemisphere (left 79.36% right 81.84%The only significant first order interaction was hand x condition, $p < .05$, table 8.4, figure 8.5, where the maxima at condition c in the main effect for condition can be seen to result from a peculiar leap in percent correct at condition c for the left hand. There were no other significant first order effects.

There were no significant triple interactions.

The mean handedness score for males was 2.31, standard deviation .37, for females 2.42, standard deviation .33, and overall, 2.37, standard deviation .34.

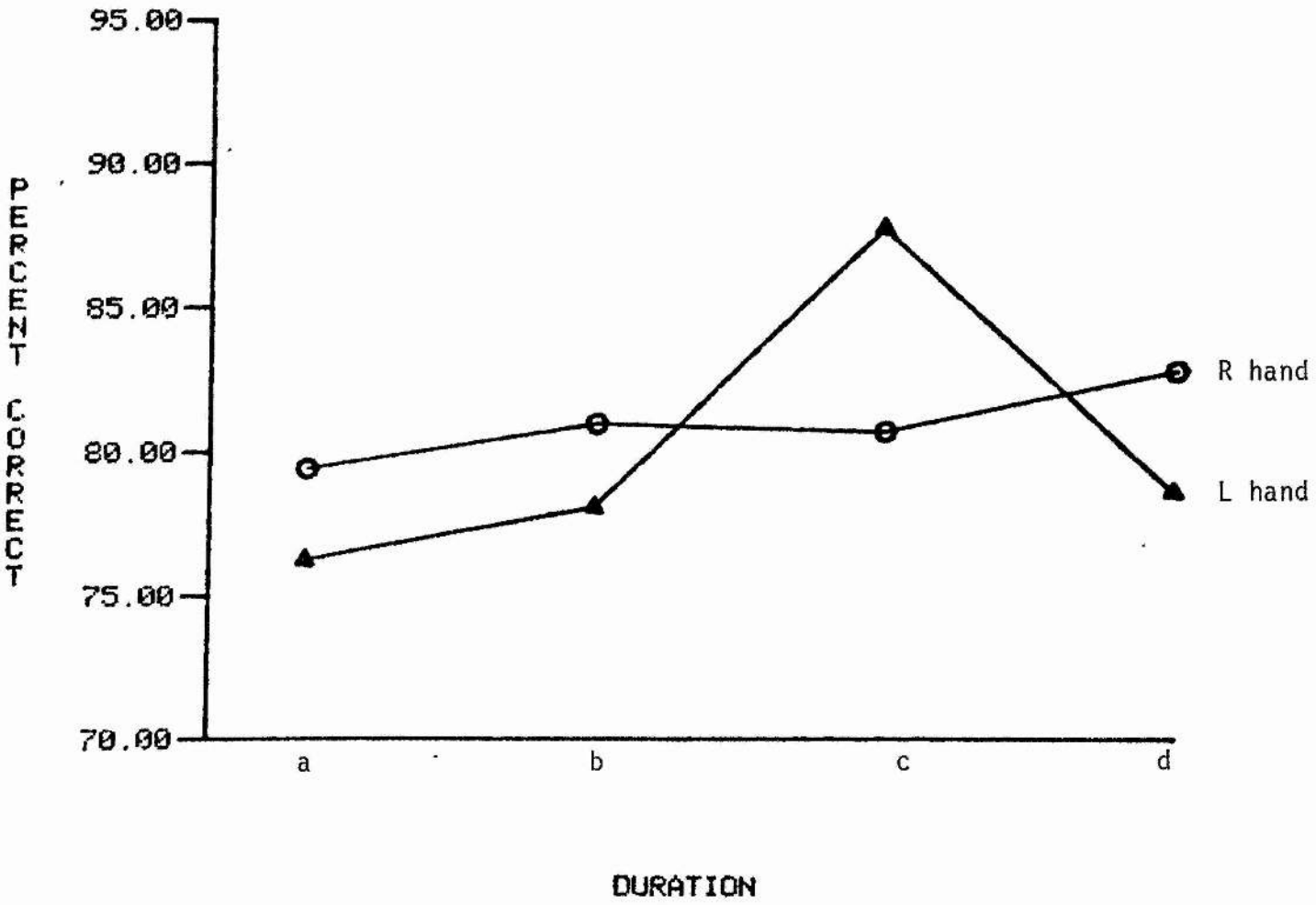
Three (male) subjects reported using no sub-vocal verbalization during the experiment; five subjects (two male, three female) reported using sub-vocal verbalization initially until the response became practiced. Five

FIGURE 8.4



Experiment Six. Percent correct responses as a function of increasing stimulus duration.

FIGURE 8.5



Experiment Six. Significant hand X stimulus duration interaction. Percent correct responses show a different pattern for the two hands with increasing stimulus duration.

subjects (two male, three female) used sub-vocal verbalization throughout; three subjects (one male, two females) mediated their responses with sub-vocal verbalization for most of the experiment. The first eight subjects described constituted the "no" group, the latter eight the "yes" group.

It was expected that subjects who reported using sub-vocal verbalization would give higher left hemisphere correct minus right hemisphere correct scores. For the "yes" group, mean L-R = 0; "no" group, mean L-R = -4.5 (in the expected direction). [These are raw data scores.] However, a t test which compared the groups was nonsignificant (t = 1.18).

	Percent Correct
Field Duration a	77.86
Field Duration b	79.56
Field Duration c	84.24
Field Duration d	80.73

Table 8.3

	Percent Correct	
	Left Hand	Right Hand
Field Duration a	76.30	79.43
Field Duration b	78.12	80.99
Field Duration c	87.76	80.73
Field Duration d	78.65	82.81

Table 8.4

Discussion

In this experiment, we examined whether there were differences between the cerebral hemispheres in their ability to differentiate between the shapes of stimuli moving in the visual field. The shapes were squares and diamonds, camouflaged in a random texture field until revealed in apparent motion.

The shapes were displaced in the visual field such that they were lateralized to either the left or right cerebral hemisphere. The subjects task was to identify the shape in motion, irrespective of the side on which it appeared or type of movement perceived, and respond manually.

The dependent measure was the number of shapes correctly identified.

Stimulus conditions (e.g., low contrast, or a masking ISI) which in previous experiments in this series had been shown to result in hemispheric differences, were eliminated from this study.

As might be expected, the number correct increased with increasing stimulus field duration ($p < .05$). Strangely there was a maximum at duration c. The significant field duration x hand interaction ($p < .05$), figure 8.5, shows that this maximum is due to the left hand data. In a right handed subject population there is no

plausible account for this effect. (Field duration x hand x hemisphere was very nonsignificant, $p = .850$.)

Shape was highly significant, $p < .001$. Subjects detected squares at a rate of 90% correct; while diamonds were correctly detected on 71% of presentations. This occurred despite diamonds extending slightly closer to fixation (0.4^{o} VA). The irregular edges of the "diamonds" may have resulted in better camouflage than the straight edges of the moving squares. The difference implies that generally subjects did not adopt a strategy of detecting "squares" and "non squares," but attempted to identify the shapes based on the individual configuration of each.

It is possible that the response "diamond" was more difficult semantically. However, this conjecture is not supported by a strongly nonsignificant hemisphere x shape interaction ($p = .523$).

There were no other significant main effects for the other variables entered in the analysis, i.e., sex, trials, hand, or hemisphere. And no other first or second order interactions.

The pilot studies showed that the percept of motion remains for briefer stimulus durations than the percept of what is moving. Confirming that detecting motion is a more basic visual ability than identifying the shape of a moving object. Given this, we expected that perhaps the hemispheres might be disparate in the percent of shapes

correctly identified in the current experiment. A number of possible differences will be considered.

If the response was verbally mediated, one would expect left hemisphere superiority. No such main effect was observed. Reports of sub-vocal verbalization were somewhat ambiguous since the majority of subjects used sub-vocal verbalization for part of the experiment and ceased as they became familiar with the task. However, subjects were assigned to "yes" and "no" sub-vocal verbalization group as accurately as possible. For the "yes" group (implying left hemisphere activity), the overall mean left hemisphere minus right hemisphere difference for raw scores was zero. For the "no" group, this difference was -4.5 (in the expected direction for right hemisphere activity). But a t-test showed that the two groups did not differ significantly on percent correct scored by the cerebral hemispheres. Also, if generally as subjects became practiced on the task, they ceased using sub-vocal verbalization and hence left hemisphere mediation, one would expect a hemisphere x trials effect with the left hemisphere better initially. No such result was obtained (hemisphere x trials, $p = .614$).

The preceding findings tend to argue against a left hemisphere verbally mediated approach to the current task. However, the use by some subjects of verbalization by both hemispheres is not precluded. Zaidel (1975), after testing commissurotomy and hemisphereectomy patients on

the token test, concluded that "the right hemisphere can comprehend size adjectives, colour adjectives and shape nouns when they are presented in isolation with a small choice array." Other split brain studies have shown the right hemisphere's ability to process nouns (Gazzaniga & Sperry, 1967; Gazzaniga, 1970; Gazzaniga & Hillyard, 1971).

On a purely perceptual nonverbal task, one would expect the right hemisphere to be superior. The "no" sub-vocal verbalization group did on average show higher right hemisphere scores, but the difference between this group and the "yes" subjects was not statistically significant. Also the nonsignificant main hemisphere effect, $p = .487$, clearly shows no difference between the hemispheres overall. Thus on a purely perceptual account of the results, the left hemisphere is not significantly inferior to the right.

The left hemisphere could have mediated its decisions verbally, while the right responded to the stimuli on a perceptual basis. However, in this case, the left hemisphere has to first visually identify the shape before assigning a verbal label. In this initial perceptual detection, the results show the left to be no worse than the right cerebral hemisphere.

The studies reviewed in chapter one and cited in the introduction to this chapter, which have used stationary shapes as visual stimuli, have yielded mixed or no

hemispheric dominance effects. The outcome of the current experiment is not inconsistent with these results. We found, for the experimental paradigm used, that for normal right handed subjects, there is no difference in cerebral hemispheric ability to identify moving shapes.

CHAPTER 9

DISCUSSION

INTRODUCTION

The reported experiments constituted a series of studies on the visual perception of motion. Under specific scrutiny was the possibility of differences between the cerebral hemispheres in their ability to process visual motion information.

Subjects in all studies were normal right handed adult humans. Stimuli were viewed binocularly and responses were manual throughout. Experimental comparisons were made between the visual half fields (VFs) in detection of real motion, apparent motion under various stimulus conditions, apparent motion in the third dimension and shape recognition through apparent motion. In addition, although responses to stimuli in all experiments were manual, the possible role of verbal mediation in these tasks was discussed.

MOTION PERCEPTION

The analysis of visual motion appears to be a visuo-spatial task. However, the path of an object in motion must also be described in terms of a series of positions in time. The right hemisphere is traditionally viewed as being visuo-spatially superior, whereas the left is considered to be dominant for sequential processing. It is therefore not immediately obvious which hemisphere should be more accurate when confronted with a difficult motion detection task. Indeed, the current series of experiments show that one hemisphere is not consistently superior for motion detection. Shifts in VF accuracy occur for changes in stimulus conditions.

Five of the current experiments studied apparent motion and one real motion. As was discussed in chapter four, apparent motion has been empirically studied since Exner (1875).

Wertheimer (1912), Gibson (1954), Gregory (1966) and Frisby (1972), consider that real and apparent motion are mediated by the same neural mechanism, whereas Kolers (1963, 1964, 1972), believes that "the neural mechanisms for the two types of perception must be quite different."

The present series of experiments cannot resolve a controversy which has continued for a hundred years. Indeed, Sekuler (1975) has criticised such attempts: "Among the issues that have generated much theoretical heat without the help of much experimental light, is the relationship between real and apparent motion."

REAL AND APPARENT MOTION

Over the last decade, new apparent motion stimulus configurations have been studied which have extended the discussion on motion perception. These recent developments will be reviewed here.

In the majority of experiments reported in this thesis, the stimuli used were random black and white texture fields in which a lateralised small shape was defined in S1 and its relative position shifted in S2. With appropriate tachistoscopic presentation, the small shape may be viewed in apparent motion.

Motion percepts produced by such stimuli have been extensively studied by Braddick (1973, 1974) and discussed by him (1980). He reports that random dot stimu-

li give apparent motion percepts which differ from the apparent motion of traditional stimulus displays.

Braddick (1974) found that when the target shape was displaced by more than 15' arc, coherent motion of the figure broke down and it could not be differentiated from the background. (In this experiment, backgrounds in successive presentations were uncorrelated). This breakdown effect depended on the actual displacements in visual angle (VA), rather than on the number of texture items through which the shape was moved. Also, for dichoptic presentations, good motion was rarely reported.

Studies in the present series revealed similar effects. These are discussed under the heading "Apparent motion in the 'wrong' direction", on pages 132-136. The task was to correctly report the direction of motion of a stimulus square. It was found that if its displacement was two or more items of texture,(ie., over 25' arc) the direction of motion became ambiguous for the majority of observers. One dot displacements, 12.6' arc, were therefore chosen for use in the experiments proper. These observations support Braddick's (1974) findings since the values at which breakdown occurred are very close to his results despite the difference in experimental paradigm. (Identical vs. uncorrelated backgrounds; direction of motion vs. orientation of

figure).

For the majority of observers, with two or more item displacements, the direction of motion was of an ambiguous, bi-directional, nature. But motion was clearly perceived as was shape. Some subjects also saw bi-directional jumpy motion for one item displacements. That is, displacements of two texture items under "optimal" viewing conditions could produce for most observers the bi-directional movement, due perhaps to confusion between the movement of the displaced square (down say) with the relative induced movement upwards of the immediately surrounding background dots. For a minority of subjects, this relative movement seems to have been produced strongly enough by one item displacements to make the direction of motion ambiguous. However, there was also a potentially more interesting sub-group who, for one item displacements, reported clear one directional motion but in a direction opposite to the square's displacement.

Clarification of these results further than the discussion on pages 132-136 would require an extensive series of psychophysical experiments with the various groups of subjects. Such a series was beyond the scope of the current hemispheric studies. However, the phenomenon may be due to some subjects being more sensitive

to relative or induced movement of the background, and responding to this. Induced movement using an annulus of spatially random dots, on a CRT screen, surrounding a smaller central section of similar dots has been discussed by Sekuler (1975). When the annular dots drifted across the screen, the stationary central dots appeared to move in the opposite direction. These induced motion effects were explained "in terms of lateral inhibition between motion analyzers sensitive to opposite directions of motion. Imagine that the elements which respond to the movement of the surround inhibit neighboring elements (in the center of the field) sensitive to that same direction of motion. Induced motion might then result from the imbalance (in the field center) of spontaneous activities in (1) elements sensitive to the surround direction and (2) elements sensitive to the opposite direction. This explanation of induced motion is quite speculative." And inter-subject differences in the current studies remain problematical.

Braddick (1974, 1980) suggests that apparent motion may be described in terms of low-level "short-range" processes which govern motion percepts of stimuli separated by .25 deg. or less, and higher level processes responsible for apparent motion between stimuli separated by greater displacements.

Data in support of Braddick's "short-range" process are provided for example by Lichtenstein (1963) who studied apparent motion using square wave oscilloscope patterns. Displacements were between 0.4' VA and 8.5' VA. He concluded that apparent and real movement were on the same perceptual continuum.

Thorson et al. (1969) and Biederman-Thorson et al. (1971) presented 1ms. duration lights separated by 6'-10' arc, positioned 22 deg. peripheral to the fovea. When flashed on simultaneously or at short ISIs, these stimuli appear as a single dot. At sufficiently long ISIs, two flashes spatially superimposed are reported. However, for ISIs around 50 ms. there is strong apparent movement in the direction of the sequence. The extent of movement is perceived as being considerably greater than the actual displacement. Discussing their results vis a vis classical apparent movement paradigms and real movement perception these scholars appear to precede Braddick (1974) in their conclusions. They suggest that their fine grain apparent movement is stimulating the real movement perception system and that classical apparent movement involves a different higher level system which "rationalises" widely spaced flashes as motion. Additionally they note that the same stimulus parameters fit both their fine grain apparent movement and metacontrast (backward masking), implying a

common mechanism.

An apparent motion stimulus configuration in which a horizontal row of three dots, each separated by 1 deg. VA, is alternated with three identical dots displaced to the right by one dot position (the Ternus display), was studied by Pantle and Picciano (1976), and Petersik and Pantle (1979). The two "central" dots are spatially superimposed. Under apparent motion conditions, the percept is either of the end dot moving between the outside positions while the central dots remain stationary, "element movement"; or "group movement" in which the three dots oscillate as a unit. Group movement tends to predominate for: longer ISIs, brighter ISIs, lower stimulus contrast, and greater subject light adaptation.

Petersik and Pantle postulate an "E (eta) process" which mediates element movement, and a "G (gamma) process" which is responsible for group movement. They also identify Braddick's short-range apparent motion with the E process, and suggest that the G process mediates more global motion percepts such as those studied by Pantle (1973), and Ramachandran et al. (1973).

Shepard and Judd (1976) studied apparent motion between alternating pairs of views of three dimensional figures. The two views of the object are presented in

the same spatial location but with a relative perspective rotation. When stimulus durations are longer the object seems to rotate as a rigid whole throughout its trajectory. For shorter durations, different parts appear to move independently or to deform into other non corresponding parts. Petersik and Pantle (1979) suggest that the sensation of rigid coherent movement and the sensation of plastic noncoherent movement described by Shepard and Judd are mediated by the same same processes as the group and element movement percepts, ie., the G and E processes respectively.

However, it seems that the angular displacements of these stimuli might be too great to qualify as "short-range processes", although this is difficult to judge since Shepard and Judd do not specify visual angles. Since Petersik and Pantle suggest mediation by the G process of the rigid coherent motion of the Shepard and Judd figures, and E process mediation of the plastic noncoherent movement, they would presumably also associate "space" percepts of the moving V in experiment five of the current series with the G process and "plane" responses with the E process. Yet in these stimuli the apex of the V moves through 3 deg. VA. Petersik and Pantle should also predict that for such stimuli, space reports would approach 100% for dichoptic viewing (from Pantle and Picciano 1976). There does not

seem to be an empirical study which examines this.

Braddick (1980) points out regarding the Petersik and Pantle (1979) stimulus setup and account, that in "element" movement (attributed to the short-range process), the dot traverses about 3 deg. VA, a distance considerably greater than the limit set in his (1974) studies. Whereas in "group" movement (attributed to the higher long-range process) the individual dots apparently move 1 deg.

Braddick (1980), using a three line Ternus display, presented (a) all lines dichoptically (b) the inner lines dichoptically (c) the outer lines dichoptically. In (b) and (c) the outer and inner lines respectively were seen by both eyes. For (a) group movement predominated - about 75% of reports, for (b) group movement - about 50% of reports, for (c) group movement - almost 0%, ie., element movement reported. Braddick interpreted these results as indicating that the inner stimuli activate the short-range process which signals no movement.

Braddick, on the basis of his 1974 work, proposed that apparent motion is mediated by two processes: one, a "low- level", "short- range" process identified with the responses of directionally selective neurons; and

two, a "higher-interpretive" system which responds to traditional "long-range" apparent motion. The "short-range" process also handles real motion, whereas the "long-range" process does not (Anstis, 1978). The "short-range" process is considered to occur at an earlier stage in the visual system, ie., prior to binocular integration. (Braddick, 1974).

But the question remains, why should the visual systems of man and other species (Grusser and Grusser-Cornehls, 1973) have evolved to include a mechanism which interprets as moving certain stationary sequentially occurring stimuli? This may be resolved by suggesting that for real motion which exceeds the operating limits of a "primary" motion detecting system, a "secondary" mechanism takes over. The latter system would process rapid real motion and be triggered by "long-range" apparent motion displays for which the "calculated" velocity of the stimulus is high.

Kaufman et al. (1971) hypothesised that apparent motion begins at a point where the perception of real motion begins to deteriorate into a blurred image. Using an apparatus which could present either real or apparent movement, Kaufman et al. (1971), found that the velocity at which real motion became blurred (8-10 deg./sec) was also the lower threshold for apparent mo-

tion. The upper limit at which the real motion percept broke down completely did not differ significantly from the apparent motion simultaneity threshold. They also observed that if the stimulus was seen as stationary before and after its displacement, it could be seen more clearly at higher velocities than if it was moved continuously. These authors do not discuss their results in terms of "low-level", "short-range" vs. "higher-interpretive", "long-range" processes (their paper predates Braddick, 1974). But they do suggest that apparent motion serves to extend the range of motion perception beyond the limitations set by elements early in the visual system.

For conditions of blurred real motion, the visual system is clearly operating at close to its limits. Considering the survival of the observer, the most important features of the moving stimulus are its size and velocity. Its exact shape and colour etc. are less immediately vital. Thus it may be speculated that when "important" stimulus parameters (eg., position) are changing at a rate close to the visual system's processing threshold, only the most salient stimulus features will be dealt with on a continuous basis. Information which is less relevant ("perceived" by the system under less stressful conditions), such as the moving object's exact contours, or no longer relevant, such as the ob-

ject's previous position, would not receive high processing priority and be filtered, suppressed or ignored.

It may be further suggested that since many of an object's parameters remain constant during motion, it is unnecessary for the visual system to completely "redescribe" the object at every point on its trajectory. After a more "detailed description" of the quickly moving object has been made, an ongoing "loose description" must of necessity suffice.

Decreases in contrast, or disappearance of stimuli presented early in apparent motion sequences has led researchers to link apparent motion and visual masking (eg., Kahneman, 1967; Weisstein and Growney, 1969). An apparent motion setup which seems to give percepts paralleling the indistinctness observed in fast real motion may be produced by the following display: On a white disc, a clear black radial line is drawn from the circumference part way towards the centre. The disc is rotated and stroboscopically illuminated. Depending on the number of flashes and the inter flash interval, the observer perceives one, two,...n lines moving round the annulus of the disc. The number of lines seen is limited by the persistence of vision (Efron and Lee, 1971). Mackenzie (1971) observed that when a group of n lines is seen in apparent motion, the leading line (ie., the

one last presented), appeared most distinct, with a decrease in the apparent contrast of each following line. Lines presented in positions prior to the n were often not seen. Conditions which gave rise to the strongest apparent motion percepts also produced the most pronounced blanking effects. Breitmeyer et al. (1974) found that for optimal apparent motion, contour detail of the stimulus is also maximally suppressed.

A blurring effect in an experiment examining optimal apparent motion during a 15 second viewing period, which precluded the use of single line stimuli, is noted by Frisby (1972a). "The perception of a single line moving to and fro would break down and be replaced not with the perception of two separate lines flashing on and off alongside one another, but rather with the sight of a shadow or 'black area' moving from side to side in front of a bright patch of light."

Apparent motion may be observed between different outline figures (Kolers and Pomerantz, 1971). This should not be considered as too surprising. Natural stimuli, eg., flying birds, frequently change their contours while in motion.

Against Braddick's (1974) short-range, long-range dichotomy is the point that it is not exactly clear from

Braddick's figures why he chose 15' arc as the upper limit of the short range process. There is no marked change in performance at this value. Thus a single system may in fact be operating. Also, Braddick (1980) using a rotating annulus, obtained data indicating the short-range breakpoint to be around 30' arc. On the other hand, perhaps one should not expect abrupt switches between mechanisms in the sensory system but rather a gradation through an area of overlap. Also as Braddick points out, his 1980 data were obtained from more peripheral stimulation. Changes in threshold values are often observed as retinal distance from the fovea increases. The ambiguous motion found in the present studies also shows that for most observers the limit for accurate direction detection is in the range 12' to 25' arc, which implies a threshold for a visual motion system in this range.

It is not obvious from Braddick's writings whether he would agree with the view that fast real motion and long range apparent motion are mediated by the same mechanism.

Generally the evidence appears supportive of Braddick's short-range, long-range description, and as will be discussed, writers such as Kolers, who favours a two mechanism model of real and apparent motion, and Ullman,

who seems to favour a single mechanism account, both appear to be consistent with Braddick on certain points.

Kolers maintains that different mechanisms mediate real and apparent motion. He seems to particularly argue against identifying "long- range" apparent motion with perceptually clear real motion. Typically he has studied "traditional" apparent motion displays. However, Kolers (1972) reported an experiment which Braddick (1974) has interpreted as supporting the long-range, short-range dichotomy. Kolers (1972) studied the apparent motion percepts obtained when differing numbers of lines were presented sequentially on a CRT screen. He found that for 2 lines good apparent motion could be obtained, while for n greater than 2, the lines had to be separated by 14'arc or less (32 lines in this experimental paradigm) to give good motion percepts. Kolers considers as analogous to real motion his 1024 line case and describes the percept as "continuous motion". He also describes the 32 line case as "smooth continuous motion" (though its quality varied with presentation speed) and also as "apparent motion". Thus Kolers seems to be identifying short-range apparent motion with real motion. He certainly does in the 1024 line case and presumably also for smaller ns. Perhaps for n=32, VA=14' arc ?

However, on considering Kolers writing on the parameters which define classically studied apparent motion and real motion, it seems that he does not regard the long-range apparent motion mechanism as one which enables the velocity range of real motion perception to be extended.

Unlike Kolers, Frisby (1972) expresses the view that a single "mechanism" (subject to certain definitional constraints) mediates both real and apparent motion. Therefore he would also presumably also reject the short-range/long-range dichotomy.

Ullman (1979) adopts a computational approach to motion perception. Using two "frame" apparent motion dot displays such as those studied by the Gestalt perceptual psychologists and Kolers (1972), he examines the "correspondence process" ie., the means by which differing views of an object in different places are perceived as a single object in motion. This process is accomplished according to Ullman by the matching of elementary "correspondence tokens".

It seems that Ullman may be interpreted as being in favour of a single mechanism account of real and apparent motion, since he suggests that apparent motion perception may involve only part of the real motion mechan-

ism. He criticises Pantle and Picciano (1976) for postulating two separate mechanisms to account for the bistable nature of the Ternus display, claiming that his "competition scheme" (the process by which correspondence is computed) can account for the change in percept from element to group movement.

For Ullman, continuous (real) motion perception is merely an extension of the process which computes the matches in the two frame cases. However, in apparent contradiction to the above formulation, Ullman also accepts the possibility of Braddick's long-range and short-range processes.

Generally, Ullman's account is reminiscent of Gestalt perceptual psychology, for example, his use of concepts such as "affinity" - roughly a measure of similarity between tokens. Whether his system is more than a mathematical formalisation of Gestalt like concepts remains to be seen.

Concerning the level in the visual system at which the motion mechanisms may be located, Braddick (1980) tentatively identifies his "short-range" process with the response of directionally selective neurons. Extrapolating to humans the findings of Hubel and Wiesel for the cat (1962) and monkey (1968), suggests that

these neural units do not occur at levels prior to the striate cortex. Therefore, applying the term "peripheral" to the "short-range" process may be somewhat misleading. From his dichoptic studies, Braddick suggests that the "long-range" process is located at a higher level. Regarding the differentiation between peripheral and central masking, Turvey (1973) states "the definition of peripheral that has been implicit in the preceding discussions is one which includes retina, lateral geniculate nucleus, and striate cortex as its components."

If the arguments identifying fast blurred real motion and long-range apparent movement with the same processing system are correct, this would predict certain empirical outcomes. Short range apparent movement gives good motion after effects, whereas long range apparent movement gives little or none (Anstis, 1980). Thus, one would expect that fast blurred real movement would also generate poor motion after effects. This is in fact the case. See eg., Sekuler and Ganz, 1963. Adaptation to slow or blurred real motion should have more effect on the subsequent viewing of short range or long range apparent motion respectively. And conversely.

REAL AND APPARENT MOTION SUMMARY

Recent work on motion perception has been reviewed with the aim of accounting for the phenomenon of apparent motion in terms of real movement mechanisms. Data from a number of experimental paradigms, and discussions from from various theoretical viewpoints have been presented. From these, one may plausibly draw the following conclusions.

Within the movement detecting system, two components may be identified. One of these does not selectively process real motion and the other apparent motion as has been suggested by some theoreticians. Rather, component one, occurring earlier in the visual system, processes real motion for velocities up to those at which blurring is observed, and apparent motion for which stimulus displacements are small ("short-range"); component two produces output from rapidly moving (blurred) real motion stimuli, and apparent movement over greater displacements ("traditional" or "long-range"). "Short-range" apparent movement is a small inductive step from real motion. "Long-range" apparent movement and high velocity real motion are phenomenologically very similar. Component one is tightly stimulus-bound, whereas component two is freer, more creative and capable of "editing" stimulus input.

MASKING OF RANDOM DOT STIMULUS MOTION

Braddick (1973), using random dot stimuli, found that a bright ISI masked apparent motion which could be seen for a temporally equivalent dark ISI. In experiment four of the current series, it was found that when a bright ISI was used, masking of motion was observed. Stronger masking was obtained when the duration of the bright ISI was increased. However, if instead of being switched off during the stimulus presentations and on again for the ISI, the background field (at the same brightness) remained on continuously throughout the stimulus sequence, no masking was observed, and increasing the duration of this ISI over the same range did not produce masking.

The masking effect reported by Braddick (1973) does not therefore result from having a bright vs. a dark ISI. Rather the visual mechanisms are disrupted by abrupt changes in stimulus intensity. The latter is a previously unreported finding.

A consideration of the four stimulus conditions (figure 6.1) shows that the results of experiment four cannot be explained in terms of contrast or overall luminance. These observations corroborate Braddick's

(1973) studies. He did however report that at low contrasts the clarity of the moving figure did drop off substantially. This effect was used to produce the threshold data in experiment two of the current series. Phenomenologically, the inability to correctly detect the direction of motion seems to occur for different reasons in the masking ISI and low contrast situations. In the latter case, the uncertainty arises due to indistinctness of the stimuli, while in the former, perception seems to be upset by the flash of the ISI.

A dichoptically presented bright ISI did not produce motion masking (Braddick, 1973). In backward masking experiments forms are not masked by dichoptically presented homogeneous flashes of light. These findings indicate that it is the sub-cortical visual system which is affected by this type of masking. (Mowbray and Durr, 1964; Schiller and Wiener, 1963; Smith and Schiller, 1966).

In experiment four, there was a significant VF effect for the masking ISIs, but no VF X ISI duration interaction although overall masking increased with ISI duration. As will be discussed later, this suggests a primarily sub-cortical locus for bright ISI motion masking.

THEORIES ATTEMPTING TO ACCOUNT FOR VISUAL FIELD DIFFERENCES

GENERAL INTRODUCTION

As was discussed in chapter two, when a human subject is fixating a central spot and a visual stimulus is flashed up in a position greater than 2.5 deg. VA lateral to fixation, the stimulus information is transmitted initially to the contralateral cerebral hemisphere. Figure 2.1. A number of neural processes may then ensue. For example, the stimulus may be processed by the recipient hemisphere without involving the contralateral hemisphere. In more complex scenarios, stimulus information may be transferred across the corpus callosum with or without prior processing and identification, processing if begun, may then continue or cease in the original hemisphere while it proceeds in the second hemisphere. Further decoding or memory matching may involve additional trans callosal transmissions. So too may response output.

In split brain subjects, because of callosal section, there is usually less argument about which hemisphere is doing the processing and responding. However, Trevarthen and Sperry (1973) have discussed pathways by means of which inter cerebral communication may occur

without a corpus callosum.

For intact adult humans it is often difficult to decide with certainty on the laterality of processing. Reaction time studies (aside from simple RT experiments using for example light flashes as stimuli) may not even clarify the issue since often one cannot separate trans callosal transmission time from processing time, which may differ in the two hemispheres, especially when such factors such as hemispheric priming are taken into account. (Swanson et al., 1978).

Split brain studies have shown that while the right hemisphere appears to lack a verbal output mechanism, it may successfully interpret simple words. (Gazzaniga and Sperry, 1967, Levy and Trevarthen, 1977, Levy et al., 1972). However, it is deficient in analysing verbal commands (Gazzaniga, 1970), and adjectival phrases, (Zaidel, 1977).

Thus in experiments using vocal responses one must consider that probably only the left hemisphere is capable of such output and the right is therefore disadvantaged. This problem does not arise in the current studies, since manual responses were used. With verbal stimuli, there is some considerable argument as to the level of the right hemisphere's competence and the pro-

cessing strategies which it uses. It is debated whether the right hemisphere matches written verbal stimuli on a semantic or visual-orthographic basis. It has also been suggested that the right hemisphere, although able to process verbal stimuli, is so slow that in normal subjects the left hemisphere always wins a "response race" despite inter hemispheric transfer. These points have been discussed and examined empirically by Moscovitch (1973). Behaviourally, in an intact brain, a response race with the left always winning would be equivalent to only the left hemisphere analysing the stimuli.

Discussion of such issues is pertinent when there is empirical doubt as to the ability of a particular hemisphere to perform a specific task. In such cases one cannot automatically assume that the hemisphere contralateral to the visual field in which the stimulus is presented is doing the processing.

The literature reviewed in chapter one shows that:
deficits in motion perception may result from injury to either hemisphere (Riddoch, 1917);
both hemispheres of split brain patients are capable of making motion judgements, (Trevarthen and Sperry, 1973);
apparent motion may be simultaneously observed in both visual fields, (Carter, 1953).

It therefore seems implausible to suggest for example that the right hemisphere alone processes all stimuli in the current experiments irrespective of the VF in which they are presented, since it appears that both hemispheres are capable of processing and responding manually to this class of stimuli.

Therefore, it is proposed to first attempt to account for experimental outcomes by assuming that stimuli presented in the LVF are processed by the right hemisphere and RVF stimuli by the left hemisphere and invoke more elaborate explanations only when this simple account fails. It will be initially assumed therefore that both hemispheres are capable of the analyses required, but that the hemispheres may differ in performance levels, sensitivity to adverse stimulus conditions, learn or fatigue at different rates, or in more complex tasks, use different processing strategies.

FUNCTIONAL THEORIES

Researchers conducting early psychophysical experiments were aware that the abilities of the human cerebral hemispheres were not identical, and results which showed visual field differences were consequently expla-

ined in hemispheric terms. (Stevens, 1908a, Stevens and Ducasse, 1912, and Dallenbach, 1912[23]). The latter reported that when lights in the two visual fields were judged equal by right handers, those in the LVF were physically less intense. He concluded, "From the neurological point of view the effectiveness of position may be explained by the integration of the neural connections. The processes which lead from the rods and cones of the right retinas (those excited by stimuli to the left) center in the right hemisphere of the brain and there arouse excitations which, because right-handed people are left brained, are not interfered with by other excitations. Both our Os were right handed; so that this explanation would have added plausibility if it should prove, by extension of this experiment, that the right handed position has an attentional advantage for left-handed people. From a biological point of view the most probable source of danger for primitive man was from above. The early reptiles and other gigantic beasts of prey struck down. This would account for the attentional advantage of the position above. Continuing this imaginative trend of thought, the advantage of the left may thus be explained: when man became man's greatest danger it was the weapon held in the antagonist's right hand and therefore appearing at the left which demanded attention. Speculation, of course!" (Dallenbach, 1912[23]).

Dallenbach's "explanation" contains errors and inconsistencies, eg., the large prehistoric predatory reptiles were extinct long before early man appeared, left handers are just as likely as right handers to meet a dextral foe, and the question of why hand preference arose is avoided. However, he should be commended for admitting that his account is speculative. Many modern theoreticians appear eager to promulgate conjectures on the basis of minimal or ambiguous evidence without giving caveats, eg., Levy (1974).

More recently, functional asymmetry has been a viewpoint maintained by many researchers, for example, McKeever and Huling and Kimura and her co-workers.

Broadly, this theory states that for the majority of right handed normal adults, superior processing will be observed for linguistic stimuli presented in the RVF, ie., to the left hemisphere; whereas the right hemisphere will process visuo-spatial stimuli more efficiently.

The literature reviewed in chapter one shows that the functional theory stated without further assumptions and additions cannot accommodate all the visuo-spatial or linguistic data. Despite this, the evidence is

overwhelming that the cerebral hemispheres are not equivalent in their processing of all visual stimuli. Generally the functional model is the most parsimonious explanation for VF differences and later in this chapter attempts will be made to account for the results of the current experiments in terms of the differing capabilities of the cerebral hemispheres.

"FUNCTIONAL LOCALISATION" MODEL

Moscovitch (1973) has proposed a model which attempts to reconcile observations on brain injured patients, which have led some neurologists to conclude that verbal functions are localised exclusively in the dominant hemisphere whereas nonverbal functions are predominantly but not exclusively lateralised in the minor hemisphere, with split brain studies which suggest that language functions are represented in both hemispheres though usually more strongly in the left. The model which Moscovitch (1973) terms the "functional localisation model" states that the verbal competence of the minor hemisphere of normal and aphasic people is equal to that of split-brain patients. But if critical portions of the dominant hemisphere and cerebral commissures remain, the verbal competence of the minor hemis-

phere is suppressed.

While suppression of right hemisphere activity by the left may be appropriate in the case of language, eg., by eliminating competition for a single speech output system, at first sight it seems unlikely that an analogous system should be observed for visual perception. This would at least lead to LVF performance decrements and at worst could be hazardous. Yet there are reports of the left hemisphere commandeering control in perceptual situations, although performing worse than the right hemisphere. These studies are reviewed by Moscovitch (1979). The possibility that an analogous effect may have been observed in experiment one of the current series will be considered when the individual experiments are discussed.

PARALLEL AND SERIAL PROCESSING

Akin to the functional model is the parallel vs. serial processing account. This suggests that the left hemisphere, being superior in language analysis, utilises serial processing whereas the right hemisphere being more skilled at visuo-spatial analysis uses parallel processing. Alternatively, it may have been that

the left hemisphere developed as the controller of sequential motor skills and this modus operandi was then utilised for linguistic purposes.

An account of cerebral organisation which could underlie parallel/serial cerebral functioning is given by Semmes (1968). On the basis of lesion studies, she suggests that capacities are focally localised in the left hemisphere but diffusely represented in the right. A diffuse system would seem more suited to parallel processing and a localised system to serial processing. However not all the clinical data support Semmes description. She herself notes earlier data of her own which implies diffuse representation of complex abilities in the left hemisphere.

Cohen (1973) attempted to account for the results of her experiments on judgements of homogeneity among a set of symbols with a parallel/serial model. A parallel process was judged to be in operation when RTs did not vary with stimulus set size; a serial process was presumed when RTs increased with the number of stimuli presented.

Cohen interpreted left and right visual field scores as indicating right and left hemisphere processing respectively. The data for letter matching showed

"same" RVF (left hemisphere) RTs lengthening with increasing number of stimulus items - therefore serial processing. "Same" RTs were constant for the LVF (right hemisphere) - therefore parallel processing. It was suggested that for "different" responses to letters, both hemispheres were processing serially. Shape matching was judged to be a parallel process for both hemispheres. Thus, from Cohen's paper, it appears that both hemispheres are capable of using either parallel or serial processing depending on the nature of the stimuli and whether they are the same or different.

The empirical differentiation of parallel and serial processes on the basis of RTs is itself problematical. Usually, for an increasing number of items to analyse, linearly increasing RTs are interpreted as indicating serial processing, constant RTs imply parallel processing. However, flat RT functions arise only for a parallel process with a constant comparison time. More complex parallel models also predict linearly increasing RT functions. (Townsend, 1972, Seamon, 1974).

The concept of parallel processing seems to be based on the intuitive idea that certain sensory inputs such as visual stimuli are at least initially processed in a Gestalt, holistic manner. Conversely, inputs such as language require sequential analysis. However, it is

not clear where parallel processing may be considered to end and serial processing begin. When viewing a scene or a picture one scans it by sequentially focussing on salient features. Also random dot stereograms presented with temporal delays may still be seen in depth. Thus, apparently parallel processes become serial.

Empirically and conceptually therefore, the parallel vs. serial dichotomy is not as clearcut as it at first appears. Consequently its theoretical usefulness as a description of hemispheric functioning also becomes dubious. This seems especially so in the current experiments since depending on ones stance on the parallel-serial theoretical continuum, one could argue that the perception of random dot patterns in motion involves parallel, serial or both processes.

EVOLUTION OF LATERALITY

An individual animal may prefer to perform tasks with a particular paw, or store specific memories in one hemisphere, but paw or hemisphere preference across species populations is evenly divided. (Hamilton, 1977). Presumably the uneven laterality distribution now found in humans has arisen due to some advantage which asym-

metrical cerebral organisation confers. While it may be tempting to speculate on the evolutionary processes which have led to functional hemispheric differentiation (eg., the nascence of language), one may in the process construct an elaborate theoretical edifice on a flimsy empirical foundation.

Levy (1974) speculates on the advantages which the evolution of cerebral asymmetry confers on a species and proposes a model to account for the proportion of left and right handers in the human population. Levy states that anthropoids which have evolved language and functional asymmetry will be better adapted than cerebrally symmetric anthropoids, the latter group being deficient in visuo-spatial processes. She cites as supportive evidence of this notion an IQ study of left and right handed students. She considers the left handers to be inefficiently lateralised, tending towards a cerebral symmetry which has produced in effect two left hemispheres and consequently Gestalt perceptive capacities will have suffered. No laterality evidence is presented to support the "two left hemispheres" notion, with respect to this particular population, although it should be conceded that bilateral language is more frequently found in left handers. For Levy's left handers, in support of her view, mean verbal IQ exceeded mean performance IQ by 25 points. However, the performance IQ of

the left handers was 117, hardly indicating a deficiency in Gestalt abilities. Other workers eg., Kocel (1977) have not found differences between left and right handers on performance or verbal IQ, thus failing to replicate the score disparity for left handers reported by Levy.

If cerebral asymmetry confers a marked advantage, then it must be explained why the evolutionary process has not eliminated left handers who tend to be more cerebrally symmetric. Levy (1974) attempts to account for this by speculating on the relative values of specialists (left handers according to Levy) and generalists (right handers) and bases her arguments on group selection. The latter idea is currently not given much credence by geneticists or ethologists.

There is insufficient evidence to contest or confirm many of Levy's (1974) points. For the same reason, it seems premature to attempt to fit the results of the current experiments into an "evolutionary" theory of hemispheric specialisation.

Levy (1974) and her colleagues (Levy, Trevarthen and Sperry, 1972, and Levy and Trevarthen, 1977) have also suggested that the type of neural organisation which best subserves language is incompatible with that

most appropriate for visuo-spatial problems and vice versa. Consequently systems for dealing with language or visuo-spatial input have developed separately in the two cerebral hemispheres.

When this view is expressed in its most extreme form, ie., that the left hemisphere is innately programmed for language and the right for Gestalt imagery, (Levy and Trevarthen, 1977), this does raise questions. While approximately 5% of right handers and approximately 15% of left or mixed handers show right hemisphere language, these individuals do not manifest any striking linguistic deficit as one might expect from Levy et al. Right hemisphere language is revealed only by drastic clinical intervention, eg., intracarotid injection of sodium amobarbital, or severe cerebral injury. Also cognitive tests of large populations of left and right handers do not reveal any significant differences between the groups on visuo-spatial or verbal scores (Kocel, 1977). Analogous arguments can be made against Levy's "crowding" suggestion that in cases of bilateral language visuo-spatial skills will suffer. The sodium amytal test shows that around 15% of left or mixed handers have bilateral language representation (Rasmussen and Milner, 1977). Yet persons with bilateral language are similarly difficult to detect. Nevertheless, the high proportion of the general popula-

tion with left hemisphere language does imply an innate propensity for this type of cerebral organisation.

In accord with Levy et al., right hemisphere functioning does often show itself to be deficient in dealing with the sequential structure of language or sequential stimulus strings (Zaidel, 1977). Conversely, although the left hemisphere is frequently shown to be inferior to the right on Gestalt abilities, these hemispheric differences are often slight and on only a few tasks has the left hemisphere failed, eg., topological geometry (Franco and Sperry, 1977), and delayed tactual pattern matching (Milner and Taylor, 1972).

From the point of view of survival, with salient objects likely to appear in either VF, an evolutionary theory should predict that both hemispheres should be equally able to correctly interpret visual stimulus information and respond appropriately. The results of the current experiments, showing VF differences for basic motion stimuli, appear counter to a strongly expressed evolutionary account, stating for example that there should be no such differences. However, it was only under threshold conditions that these VF differences appeared. Differences of the magnitude observed are not at variance with Levy's evolutionary model.

ATTENTIONAL MODELS

Kinsbourne (1970) found that for a visual detection experiment in which no laterality effects were obtained, the introduction of concomitant verbal recall gave rise to a RVF superiority in detection. He suggested that the verbal task activated the left hemisphere and caused attention to be directed to the RVF. He hypothesised that when a subject is engaged on a verbal task this produces an attentional bias towards the RVF. Processing is consequently more efficient when the stimulus appears on the right. When it occurs on the left, attention must be shifted so poorer performance results. In the case of stimuli which are of a type better processed by the right hemisphere, an analogous bias to the LVF occurs. If a subject engages in covert verbal activity, relevant or irrelevant to the task in hand, Kinsbourne suggests that this can bias attention to the right.

Kinsbourne's (1970) model has been updated in response to empirical results which were not in accord with its original predictions. One recent formulation is given by Swanson et al. (1978). They emphasise the position of the stimulus more than stimulus type or response mediation, and consequently make some apparently

contradictory statements. A lateralised stimulus is said to elicit an orientation response (OR). Efficient or fast processing is observed when for example concomitant with an OR to the RVF a verbal response is required since both are controlled by the left hemisphere. Yet later they state that an OR is elicited only when the position of the stimulus is unknown. When the VF of the stimulus is known, the OR can be suppressed by the hemisphere which is preparing to respond. The concept of an OR arising from a stimulus in a particular VF, being suppressed when the VF is known, is somewhat convoluted. Kinsbourne (1973) discusses both pre and post stimulus factors, though the relative effect of each is not altogether clear from the Swanson et al. description. It would seem that the outcome of any experiment could be explained by selectively stressing the relative contributions of pre and post stimulus orientation effects, although an attempt to apply the theory with consistency across a series of experiments might pose difficulties.

However, most researchers who use the split-field paradigm, despite the polemics, incorporate aspects of functional and simpler attentional models in their theories since one viewpoint alone cannot accommodate all the empirical data. Even fairly early on in the debate on functional vs. attentional accounts of VF results, the positions were not as polarised as the proponents of

each view might have liked to make them appear. For example, Kimura and Durnford (1974) criticise Kinsbourne (1970) for postulating "attentional" processes. But earlier in the same chapter they report no VF differences for form recognition when this preceded a letter task. Following letter recognition, a RVF superiority was observed. They say that this is an interesting phenomenon since it suggests that a hemisphere and/or a resultant scanning tendency may be "primed", and that context may be instrumental in producing laterality effects. It is not obvious how "priming" and "attention" differ. Moscovitch (1979) appears to use the terms interchangeably. Generally in the psychological literature these terms are not well defined. Nevertheless, the evidence supports the view that such effects do occur, though not as strongly as Kinsbourne would appear to believe, since several failures to replicate them have been published, eg., Hines, 1978. When they are observed, they appear most frequently to activate the dominant left hemisphere.

As was discussed in chapter two, the current series of experiments was designed with the intention of eliminating the intervention of complicating factors such as priming or attention shifts. These effects might, for example, have arisen due to using target letters at fixation, or blocks of unilateral presentations.

The precautions seem to have been successful. It is difficult to see how a uniformly applied attentional model could account for the results of an experimental series in which switches in VF accuracy were observed for changes in basic stimulus parameters. This point is encapsulated in the outcome of experiment four. While masking and non masking ISIs were interspersed randomly, a RVF superiority was observed only for masking ISIs.

Also the present finding that the reported use of sub-vocal verbalisation does not correlate with visual field accuracy differences indicates that this type of response mediation does not selectively activate the left hemisphere for these experimental conditions. This seems contrary to the predictions one might make from the theories of Kinsbourne and his colleagues.

SUB-VOCAL VERBALISATION

To examine the role of sub-vocal verbalisation in the present studies, subjects were asked post experimentally whether they had used such response mediation. On average relatively higher RVF scores would be expected from subjects employing sub-vocal verbalisa-

tion, while a LVF advantage or no difference would be predicted for non sub-vocal verbalisation users, since it has been suggested that covert verbalisation during laterality tasks activates the left hemisphere and/or biases attention towards the RVF. (See for example Kinsbourne, 1970; Berlucchi, 1974; Kimura and Durnford, 1974.)

While the difference score (RVF correct minus LVF correct) tended to be in the expected direction for the "yes" vs "no" sub-vocal verbalisation subjects, the groups did not differ significantly on this score in any of the studies, or when data from experiments 2, 3, 4 and 6 were pooled. ($t=1.24$, $df=57$).

It may be that in cases in which sub-vocal verbalisation is used, the linguistic response required in the current experiments is so simple that it is easily dealt with by the basic verbal capacities of the right hemisphere which is therefore also active verbally. It is also possible that for some (or all?) subjects who reported using sub-vocal verbalisation, this response technique was employed only by the left hemisphere, whereas the right hemisphere responded nonverbally. In any case, for these tasks, the use of sub-vocal verbalisation does not produce a RVF advantage, as a consequence of left hemisphere activation or an orientation

response to the right, as Kinsbourne's model would predict.

During the sub-vocal verbalisation data analysis, it appeared that females tended to give more frequent affirmative responses to this question than males. The number of subjects assigned to each category in all experiments in which this question was asked was therefore tabulated (Table 9.1) and a chi square performed (Chi square = 10.40, df =2, $p < .01$).

Subvocal Verbalization	Male	Female
Yes	7	24
No	23	15
Ambiguous	6	5

TABLE 9.1 - All sub-vocal verbalisation data.

It appears that overall females give significantly more frequent reports of response mediation by sub-vocal verbalisation.

This finding would indicate that when processing and responding to perceptual information, females are more likely than males to utilise language. This is of

potential interest, since poorer performance by females has been reported on many visuo-spatial tasks (Harris, 1978). It may be that this is due to attempting to use language to solve problems better dealt with on a purely perceptual basis. Or it may be that on average females are less visuo-spatially competent so are obliged to apply linguistic solutions.

THE LOCUS OF HEMISPHERIC ASYMMETRIES

The results of the current experiments seem to be accounted for best by a functional model. However, Moscovitch (1979) has proposed an information processing approach which denies that hemispheric differences occur for lower order stimulus features, but emerge when categorical encoding of sensory information takes place. Since this is at variance with the present findings, his arguments on the pertinent points must be answered.

Moscovitch (1979) states, "perceptual asymmetries consistently in favor of one hemisphere are not usually reported for the detection or discrimination of low level features such as brightness, contour, loudness, and pitch (Berlucchi et al., 1971; Bradshaw and Perriment, 1970; Filby and Gazzaniga, 1969; Jeeves and

Dixon, 1970..."

Concerning simple light stimuli, while Berlucchi et al, and Filby and Gazzaniga did not observe hemispheric differences for manual RTs, Jeeves and Dixon, and Bradshaw and Perriment both report faster responses to LVF stimuli. These results are no more inconsistent than those for letter and word stimuli reviewed by White (1969, 1972, 1973) in which differing VF superiorities are observed. Yet from the latter contradictory findings few would argue that there are no hemispheric differences for the processing of such stimuli.

Moscovitch (1979) reports a study in which, for peripheral masking, there were no VF differences. For central masking, critical ISIs were shorter for the RVF. However, Turvey, 1973, obtained the latter result for peripheral masks of longer durations than those used by Moscovitch.

While conceding that "not all studies support the general model. A number of investigators have found that perceptual asymmetries do ('not' at this point in the text appears to be a misprint) exist for the discrimination of low level features such as brightness (Davidoff, 1975)...," he counters this by, "these findings, however, are often inconsistent in that similar

studies fail to confirm them." Yet Davidoff's 1975 result replicates Dallenbach's 1923 finding.

Evidence counter to Moscovitch's claims on points which are most relevant to the current experiments has been presented. He expresses views regarding other sensory modalities which may also be disputed. For example, "low level somesthetic features such as touch and pressure seem to be processed equally well by either hemisphere." For a contrary opinion, that for most right handers, the left side of the body is more tactually sensitive, one may consult Weinstein's (1978) review.

Nevertheless, it is probably true that the structures on the left and right of the peripheral (ie., sub-cortical) visual system are functionally equivalent. (Although differences in sensitivity between equivalent points on the temporal and nasal hemiretinae, and ocular dominance, should be noted). Therefore a qualified agreement with Moscovitch (1979), that laterality differences are predominantly due to asymmetries at the prestriate cortex or higher levels, seems in order. This however does not preclude the possibility that in conditions of impoverished stimulus information, the hemispheres may differ in their abilities to give fast or accurate responses. It should be noted that studies which have reported VF differences for low level stim-

ulus parameters have typically used presentations at threshold. For example, low contrast, brief duration, or masked stimuli.

It will be recalled from the discussion of short range apparent motion and peripheral visual masking that these effects may be mediated by neural structures as high as the striate cortex. This however does not resolve the argument with Moscovitch, since he explicitly excludes asymmetries at levels prior to those at which central masking occurs.

DISCUSSION OF EXPERIMENTS

In experiment one, lateralised real motion was presented. The subjects' task was to correctly identify the direction of motion of low contrast random texture stimuli. There was no significant main effect for VF. If one supposes that LVF stimuli are processed by the right hemisphere and RVF stimuli by the left hemisphere, this finding would seem to support Moscovitch's (1979) contention that there are no hemispheric differences for low level processing.

However, there was a significant ($p<.01$) visual field x trials interaction. Thresholds set for LVF stimuli improved significantly over the two blocks of trials while RVF thresholds did not, this is a result which seems to require some explanation. The simplest account is that LVF stimuli are processed by the right hemisphere whereas RVF stimuli are processed by the left. The latter hemisphere does not improve its performance over trials, whereas the right does since it is capable of "learning" this visuo-spatial task.

However, the LVF threshold during trial one was significantly inferior to the RVF threshold, whereas for trial two the LVF threshold was non significantly supe-

rior. Therefore, a more complex explanation may be required.

Reaction time data showed that incorrect RTs (ie., responses to low contrast trials around threshold) were 800 ms slower for the LVF than the RVF during trial one, but for trial two there was no significant difference. Correct RTs showed no significant effects. It may therefore be that during trial one, the cerebral hemispheres are independently processing stimuli from the contralateral VFs, and the left hemisphere is superior at the task. For trial two, in order to maximise overall performance, LVF stimuli initially received by the right hemisphere, are transferred across to the left hemisphere for processing. Thus no RVF improvement is observed since stimuli are processed by the left hemisphere on both trials. However, LVF thresholds improve since they are mediated by the inferior right hemisphere on trial one and by the superior left hemisphere on trial two. There is no significant VF difference for trial two due to all the stimuli being processed by the left hemisphere.

An alternative account invokes left hemisphere mediation of LVF stimuli during trial one. Moscovitch (1979) has discussed studies in which the left hemisphere has apparently taken over response control in per-

ceptual situations and he has proposed (1973) a model in which the left hemisphere suppresses the output of the right hemisphere.

Similar effects may be involved in the current experiment. For both trials one and two, the left hemisphere exhibits its "everyday" dominance by responding to all RVF stimuli whether the direction of motion is clear or not. Conversely during trial one, the right hemisphere on receiving an indistinct presentation from the LVF may not respond, whereupon the left hemisphere simply "guesses"; or the impoverished stimulus information is transferred from the right to the left hemisphere which responds to the now further degraded visual trace. This results in poorer trial one LVF performance. For trial two this inefficient response system is abandoned and each hemisphere responds independently to stimuli from the contralateral VF. The thresholds are now similar since both hemispheres are now responding immediately to all stimuli.

If such "left hemisphere dominance effects" are being observed here, the left hemisphere is not suppressing right hemisphere responses in the rigid manner suggested by Moscovitch (1973). Left hemisphere intervention appears to occur during trial one for LVF presentations only when the right hemisphere was in diffi-

culty or failed to respond. Also this inefficient response mediation is abandoned for trial two. Clearly, if the perceptual system is operating in this way, what is being observed is more a default mechanism than a dominance system and a considerable degree of plasticity is being exhibited.

In summary, depending on whether one postulates left hemisphere mediation of LVF stimuli on trial one or trial two, differing accounts of the results may be made. The 800 ms difference in incorrect RTs during trial one is clearly greater than the time required simply for inter hemispheric transmission. This could either reflect, for trial one, the additional time needed for the left hemisphere to process callosally degraded low contrast LVF stimuli, or reflect contralateral hemispheric processing only, with the left hemisphere superior.

The clinical literature reviewed in chapter one indicates that when visuo-spatial decrements arise as a result of unilateral brain lesion, the injury site is more likely to be in the right hemisphere. However, motion perception may be upset by lesion to either hemisphere (Riddoch, 1917; Brain, 1941; Ettlinger, 1956). Clearly motion perception is not lateralised in the way that language tends to be. But the clinical evidence

does not eliminate the possibility that one hemisphere may be superior to the other in situations of threshold motion detection, or that there may be hemispheric differences which are a function of practice or fatigue.

With normal subjects, Bertoloni et al. (1978) found faster right hemisphere RTs for velocity discrimination, presenting many more trials than in the current experiment. Given the significant right hemisphere improvement over trials which the simplest explanation of the current interaction effect suggests, it is possible that if additional sessions had been run, an overall right hemisphere superiority might also have been observed. However, the subject time required for two staircases precluded examining this hypothesis by running a third. From the current results it would be expected that Bertoloni et al's data would show improvements in right hemisphere score over trials. However, they do not examine this variable or present data which could be analysed to test this conjecture.

It is generally the case in the literature that researchers do not examine their data for hemispheric effects which depend on practice or fatigue. (An exception being the work of Dimond and Beaumont, discussed in their 1974 book). Such effects were looked for in all the current experiments.

Experiments two, three and four studied the differential abilities of the cerebral hemispheres to process and respond to apparent motion. The stimuli were random black and white texture fields in which a lateralised small square was defined in S1 and its relative position shifted in S2. With appropriate tachistoscopic presentation, the small square may be viewed in apparent motion.

In experiment two, the stimuli were presented at threshold contrast, the latter parameter being reduced by superimposing the texture patterns on a white background field, Fb. The experimental outcome was a significant LVF advantage in the percentage of correct detections of apparent motion. The simplest explanation of this effect is to suggest a right hemisphere superiority.

This would appear to parallel Bertoloni et al's 1978 finding for real motion. However, the result does not hold for all apparent motion stimulus conditions as was revealed in the following two experiments.

The apparatus, stimulus cards and subject task were the same for experiment three. The stimulus field

durations were briefer than those of experiment two, but the contrast was higher as Fb was switched off during the presentations of the textured fields and on for the ISI. In all experiments other than experiment three, even numbers of males and females participated as subjects. However, in this experiment, there were 12 females and 4 males.

Given the empirically based theoretical view of right hemisphere visuo-spatial dominance, and males being more strongly lateralised (Kimura, 1969; McGlone and Davidson, 1973; Davidoff, 1977; Lake and Bryden, 1976; Harris, 1978), the outcome of experiment three was somewhat surprising. A significant RVF (left hemisphere) superiority was observed when the female data were analysed, while inclusion of the male data led to a suppression of the VF effect. This difference between the sexes appeared to be due to the variable data of the few male subjects. It was suggested that the RVF advantage could be accounted for in terms of a bright masking ISI as described by Braddick, 1973, having a more deleterious effect on right hemisphere performance.

The masking ISI hypothesis was examined in experiment four. Four stimulus conditions were used. Two in which Fb remains on as a constant contrast reducing background throughout the stimulus presentation, with

ISI short and long; and two in which Fb is switched off during the exposure of the random pattern stimulus fields and on for the ISI which again takes short and long values. It was postulated that the latter conditions (Intermittent Fb) would produce masking ISI effects with greater masking for longer ISIs, while the former conditions (Continuous Fb) would not.

The data supported these conjectures. For conditions in which Fb is interrupted during the stimulus presentations and flashes on for the ISI, masking of motion occurs. This masking is enhanced by increasing the duration of the ISI. Equal numbers of males and females were run in this experiment. Sex and sex x VF (hemisphere) effects were non significant. The suggestion raised in experiment three of a sex difference for this task was therefore rejected. However, a significant RVF-left hemisphere advantage was observed for the masking ISI conditions (with no significant hemisphere effect for non-masking ISIs).

The pertinent literature (Braddick, 1973; Turvey, 1973), suggests that this type of masking affects the visual system at a level prior to that at which binocular input is integrated. The non-significant hemisphere x masking ISI duration effect shows that the hemispheres are not differentially affected by increased masking

(this is illustrated in figure 6.9, page 180, conditions 1 and 2). Rather it is the masking ISI per se which gives rise to the observed hemispheric disparity. Given a degraded or interrupted stimulus from the peripheral sensory system, the left hemisphere seems better able to output an accurate percept of apparent motion; but the right is no worse proportionally when the overall masking effect is increased.

Taken together, the results of experiment two, three and four show that when confronted with the task of detecting apparent motion in random texture stimuli, different hemispheric superiorities, dependent on the stimulus parameters, may be observed. In low contrast situations with ample stimulus duration time to process a percept of motion not interrupted by a masking ISI, the right hemisphere is superior. However, when a masking ISI is interposed between the stimulus fields, there is a left hemisphere advantage. For intermediate stimulus situations (conditions 3 and 4 of experiment four), no differences are observed.

The results of these experiments are in line with published studies which compare the effects of visual masking on the two hemispheres. The work of Oscar-Berman et al. (1973), McKeever and Suberi (1974), and Cohen (1976) showed that the left hemisphere was

less affected by masking. (An exception is Oscar-Berman et al's 1976 finding of shorter LVF critical ISIs and SOAs for musical notes.)

Beaumont and Dimond (1975), for a shape matching task, report: "The clear superiority of the right hemisphere was not, however, uniform across all values of stimulus exposure....It is clear, however, that the additional stress upon the system of the exposure of the first stimulus being brief imposes particular difficulties upon the right hemisphere, which are not to be observed in the left."

Taken together, these studies seem to support the current finding of a shift from right to left hemisphere superiority. It appears that right hemisphere processing is particularly susceptible to disruption when stimulus information is diminished. This effect becomes apparent when a brief stimulus is presented, or when the stimulus is attenuated by a mask. From this, in an apparent motion study using random dot stimuli, one would expect that the left hemisphere would outscore the right for brief values of S1 (with constant ISI and S2).

The current findings should serve as a cautionary note to researchers, since hemispheric superiorities interpreted as arising from differences in "higher" pro-

cessing may in fact be due to the disparate effects of basic stimulus parameters on the two hemispheres. For example, if a bright ISI had been unwittingly used in experiment six (shapes in apparent motion), presumably more correct responses would have been made to RVF stimuli. And this could have been wrongly explained in terms of a left hemisphere superiority for moving shape identification. (Under the experimental conditions used in experiment six there were no VF differences.)

The apparent motion work of Jasper (1932), Jasper and Raney (1937) and Carter (1953) using diplopic images or three targets, is described on pages 30-31 of chapter one. In a conflict situation, apparent motion may be perceived by one hemisphere with suppression of motion in the other visual field. For right handed subjects, the left hemisphere is usually dominant. Viewings in these experiments were over a period of minutes, so changes of fixation would have occurred, contravening the strictures discussed in chapter two. Therefore it is not clear how these results relate to the current experiments. To control for eye movements it would be simple to set up the Carter three target situation using a tachistoscope and give single rather than continuous presentations. Carter (1953) makes a comment which may reveal the processes involved in his experiment, "Often the subject would report that the diplopic image that

was just flashing on and off appeared after the movement outward on the other side was completed. This implies that speed of perception may be a factor in determining in which direction movement is perceived". Taking the simultaneity work of Efron (1963) into account, with the stimulus durations used by Carter, it is likely that apparent motion would be seen towards the visual field of the stimulus which was first "perceived". Indeed, one could use the apparent motion paradigm to study interhemispheric simultaneity and temporal order, with the subject reporting no motion (i.e. simultaneity), or the direction of motion, rather than making judgements of simultaneity as Efron asked his subjects to do.

In experiment five, apparent motion depth effects produced by V shaped figures were studied. The stimuli were lateralised to either the left or right VF and subjects were required to respond according to whether the V appeared to move either in "space" or in the "plane". It was found , confirming earlier reports (Neuhaus, 1930, Kolers and Pomerantz 1971), that for short ISIs the first V moves into the position of the second (inverted) V by a deformation in the stimulus plane; while for longer ISIs the observed motion from S1 to S2 becomes a rotation in the third dimension. Thus as the ISI is increased the proportion of "space":"plane" res-

ponses increases. This experiment would seem to involve Braddick's "higher-interpretive", "long-range" process since the apex of the V moves through 3 deg. VA. However, as was discussed earlier, Petersik and Pantle would be expected to propose G process mediation of "space" percepts and E process mediation of "plane" percepts. (Petersik and Pantle also identify the G process with Braddick's "higher-level", "long-range" process and the E process with Braddick's "low-level", "short-range" process). Therefore, from Braddick's original theory, one might expect the hemispheres to differ over the entire range of ISIs, whereas from the Petersik and Pantle formulation, the hemispheres might differ only above a certain ISI duration.

For unilateral lesions which result in depth perception disorders, based on a variety of cues, the right hemisphere is more frequently implicated (Riddoch, 1917, 1935; Holmes, 1919; Brain, 1941; Paterson and Zangwill, 1944; Carmon and Bechtoldt, 1969; Benton and Hecaen, 1970; Rothstein and Sacks, 1972, Lehman and Walchli, 1975; Danta et al., 1978; Hamsher, 1978). However, for normal subjects, reports conflict about which hemisphere is superior for depth perception. Richards (1970) reports greater left hemisphere accuracy for depth judgements, while Durnford and Kimura (1971) found the right scored more correct. The latter re-

searchers do not specify the sex of their subjects, while Richards data were "collected largely from young males....There was no obvious difference between the sexes". Neither paper reports practice or fatigue effects.

From the clinical and experimental literature it appears that both hemispheres are able to make depth and motion judgements. In the current experiment, there were no VF or VF x ISI effects. This suggests that both hemispheres are making their decisions on motion in depth in a similar manner, and use the same parameters when changing from plane to space responses. The extrapolations of Braddick's, and Petersik and Pantle's theories outlined above are therefore not supported.

However, there was a significant fall in percent space responses over trials and a significant hemisphere (VF) x trials x sex interaction. The difference between the sexes over trials was most pronounced for the right hemisphere. Percent space responses fell in a steep linear manner over the three blocks of trials for males, but remained constant for females. Two possible explanations were offered: (1) greater fatigue of the male right hemisphere, (2) "learning" by the male right hemisphere that no stimuli are being presented in the third dimension. It was suggested that these hypotheses could

be tested in an experiment using Julesz stereograms. The extent to which binocular disparity detectors mediate in the current experiment could be examined by running a monocular replication, this would also give depth percepts for these stimuli.

The clinical literature on visual spatial agnosia and impairments of figure recognition is summarised in the introduction to chapter eight and reviewed in more detail in chapter one, as is the work on normal and split brain subjects for shape tasks. Briefly, the clinical syndromes occur more frequently for bilateral lesions, but when they are a result of unilateral damage, the site is more often in the right hemisphere. In experimental studies using shape stimuli with normal subjects, no clearcut hemispheric advantage has emerged. However, for commissurotomy patients, a right hemisphere superiority has been found for analogous tasks.

For experiment six, random texture patterns, in which a small lateralised square or diamond was visible only under conditions of apparent motion, were used as stimuli. The subjects' task was to distinguish which shape was moving. Basic stimulus conditions which in experiments two, three and four had given rise to hemispheric differences were eliminated from this study.

Braddick (1974) used the point at which the orientation of a rectangle became indistinct as an indicator of the threshold of the "short-range" process. Thus it could be argued that the current experiment primarily taps a "low-level" mechanism. However, shape identification involves categorical encoding for which Moscovitch's (1979) model predicts the likelihood of hemispheric differences.

No significant VF (hemisphere) effect or VF (hemisphere) interactions were observed. This appears to be in line with many published studies involving stationary shapes, e.g. Heron (1957), Terrace (1959), Kimura (1966) and Kimura and Durnford (1974), the latter unsuccessfully attempted to replicate experiments in which visual field differences for shape were reported. Analogously, no difference was found between the cerebral hemispheres in their ability to detect and identify apparently moving shapes in a random texture field.

The results did not favour an explanation in terms of overall left hemisphere language mediation, but did not preclude, for some subjects, the use of verbalisation by both hemispheres. Nevertheless, on considering the data from a perceptual viewpoint, the hemispheres did not differ significantly.

In all the random dot experiments in the current series, so that subjects could correctly detect the direction of motion, it was necessary to use small displacements of the target shape. This would entail the use of Braddick's "short-range" apparent motion/real motion component of the visual system. "Higher-interpretive" component two would be involved primarily only in experiment five, the moving Vs, and in experiment six, shape differentiation. (Though the latter is arguable in Braddick's terms).

Moscovitch's (1979) model would predict hemispheric differences, if any, for the latter two experiments. (Unless he claimed that the processes involved in experiment six do not involve categorical encoding). However the converse results were obtained. Laterality differences were found in the first four experiments which examined basic stimulus parameters. When these were controlled for, no differences were observed for the complex decisions. Moscovitch's hard line is not confirmed. It would also seem that Braddick's single mechanism theory for real movement and "short-range" apparent motion would not predict the differing VF superiorities found in the current experimental series.

Pantle and his colleagues have suggested that the G process predominates for conditions such as low contrast and bright ISIs. It may therefore be that a G process mediates all stimuli which are outwith the operating parameters of the E process. As was noted earlier, the breakdown of apparent movement in the low contrast case (experiment two) seemed to be due to indistinctness of the stimuli. This appeared very similar to the difficulty of perceiving the low contrast real motion (experiment one). Also, in experiment two, S1 was long and the ISI brief, one ms, and "continuous", ie., non masking. The percept of the masking ISI apparent motion was more flickering, like early films, and the breakdown of the motion percept appeared to occur due to interference by the bright ISI. Continuing to argue in terms of a G process, the results of the present series would imply that the higher mechanisms in the two hemispheres are different. The one in the right hemisphere is a superior processor of low contrast real motion and similar apparent motion; the left hemisphere mechanism is more competent when confronted with masked apparent motion. It is also possible to argue that the mechanisms in the two hemispheres are the "same", ie., similarly constructed and using similar processing strategies, but have different operating parameters.

The preceding theorisation is speculative and post

hoc. Yet there seems to be no simple formulation which neatly accounts for the results of these studies.

In this series of experiments on the visual perception of motion, no consistent dominance by either cerebral hemisphereshas been found, and it has been shown that shifts in hemispheric superiority may be observed for changes in basic stimulus parameters.

It is obvious that the view of simple and clear cut differentiation between the left and right hemispheres on the basis of linguistic versus visuo-spatial dominance is not tenable.

Differences between the hemispheres, especially on visual perception tasks, are both subtle and labile.

References

Annett, M. 1972. The distribution of manual asymmetry. British Journal of Psychology, 63, 343-358.

Anstis, S. M. & Rogers, B. J. 1975. Illusory reversal of visual depth and movement during changes of contrast. Vision Research, 15, 957-961.

Atkinson, J., & Egeth, H. 1973. Right hemisphere superiority in visual orientation matching. Canadian Journal of Psychology, 27, 152-158.

Ayres, J. J. B. 1966. Some artefactual causes of perceptual primacy. Journal of Experimental Psychology, 71, 896-901.

Barlow, H. B., & Hill, R. M. 1963. Selective sensitivity to direction of movement in ganglion cells of the rabbit retina. Science, 139, 412-414.

Barlow, H. B., Hill, R. M., & Levick, W. R. 1964. Retinal ganglion cells responding selectively to direction and speed of image motion in the rabbit. Journal of Physiology, 173, 377-407.

Barlow, H. B., & Levick, W. R. 1965. The mechanisms of directionally selective units in rabbit's retina. Journal of Physiology, 178, 477-504.

Basser, L. S. 1962. Hemiplegia of early onset and the faculty of speech with special reference to the effects of hemispherectomy. Brain, 85, 427-460.

Beaumont, G., & Dimond, S. 1975. Interhemispheric transfer of figural information in right and non right handed subjects. Acta Psychologia, 39, 97-104.

Benton, A. L., & Hecaen, H. 1970. Stereoscopic vision in patients with unilateral cerebral disease. Neurology, 20, 1084-1088.

Berlucchi, G. Cerebral dominance and interhemispheric communication in normal man. In Schmitt, F. O. (Ed.), The neurosciences. Third Study Program. M.I.T. Press, 1974.

Bertoloni, G. P., Anzola, H. A., Buchtel, H. A., & Rizzolatti, G. 1978. Hemispheric differences in the discrimination of the velocity and the duration of a simple visual stimulus. Neuropsychologia, 16, 213-220.

Bever, T. G. 1971. The nature of cerebral dominance in speech behaviour of the child and adult. In Huxley, R., & Ingram, E. (Eds.), Language acquisition: Models and methods. New York: Academic Press.

Bogen, J. E., & Gazzaniga, M. S. 1965. Cerebral commissurotomy in man. Journal of Neurosurgery, 23, 394-399.

Braddick, O. 1973. The masking of apparent motion in random dot patterns. Vision Research, 13, 355-369.

Braddick, O. 1974. A short-range process in apparent motion. Vision Research, 14, 519-527.

Bradshaw, J. L. & Perriment, A. D. 1970. Laterality effects and choice reaction time in a unimanual two-finger task. Perception and Psychophysics, 7, 185-188.

Brain, W. R. 1941. Visual disorientation with special reference to lesions of the right cerebral hemisphere. Brain, 64, 244-272.

Broca, P. 1865. Sur la faculte du langage articule. Bull. Soc. d' Anthropol. (Paris) Vol. 6.

Bryden, M. P. 1960. Tachistoscope recognition of non-alphabetical material. Canadian Journal of Psychology, 14, 78-86.

Bryden, P. 1970. Laterality effects in dichotic listening: Relations with handedness and reading ability in children. Neuropsychologia, 8, 443-450.

Bryden, M. P. & Rainey, C. A. 1963. Left-right differences in tachistoscopic recognition. Journal of Experimental Psychology, 66, 568-571.

Burke, R. S. & Dallenbach, K. M. 1924. Position vs. intensity as a determinant of attention of left handed observers. American Journal of Psychology, 35, 267-269.

Carmon, A., & Bechtoldt. 1969. Dominance of the right cerebral hemisphere for stereopsis. Neuropsychologia, 7, 29-39.

Carter, D. B. 1953. A further demonstration of phi movement cerebral dominance. Journal of Psychology, 33, 299-309.

Cohen, G. 1976. Components of the laterality effect in letter recognition: Asymmetries in iconic storage. Quarterly Journal of Experimental Psychology, 28, 105-114.

Coren, S. & Porak, C. 1976. Size accentuation in the dominant eye. Nature, 260, 527-528.

Cornsweet, T. N. 1962. The staircase-method in psychophysics. American Journal of Psychology, 75, 485-491.

Craft, J. L., & Simon, J. R. 1970. Processing symbolic information from a visual display: Interference from an irrelevant directional cue. Journal of Experimental Psychology, 83, 415-420.

Crovitz, H. F., & Daves, W. 1962. Tendencies to eye movement and perceptual accuracy. Journal of Experimental Psychology, 63, 495-498.

Crovitz, H. F., & Zener, K. 1962. A group-test for assessing hand and eye dominance. American Journal of Psychology, 75, 271-276.

Curry, F. K. W. 1967. A comparison of left handed and right handed subjects on verbal and non-verbal dichotic listening tasks. Cortex, 3, 343-352.

Dallenbach, K. M. 1923. Position vs. intensity as a determinant of clearness. American Journal of Psychology, 34, 282-286.

Danta, G., Hilton, R. C., & O'Boyle, D. J. 1978. Hemisphere function and binocular depth perception. Brain, 101, 569-589.

Davidoff, J. B. 1975. Hemispheric differences in the perception of lightness. Neuropsychologia, 13, 121-124.

Davidoff, J. B. 1977. Hemispheric differences in dot detection. Cortex, 13, 434-444.

Dax, M. 1836. (Published 1865). Lesions de la moitie gauche de l' encephale coincident avec l' oubli des signes de la pensee. Gaz. Hebdom, S2, 11, 259-260.

De Ajuriaguerra, J., Hecaen, H., & Angelergues. 1960. Les apraxies; varietes cliniques et lateralisation lesionnelle. Revue Neurologique, 102, 28-57.

Desilva, H. R. 1928. Kinematographic movement of parallel lines. The Journal of General Psychology, 1, 550-577.

Dimond, S. J., & Beaumont, J. G. (Eds.) 1974. Hemisphere function in the human brain. Paul Elek. Ltd.

Dixon, W. J., & Massey, F. J. 1957. Introduction to statistical analysis.

Durnford, M., & Kimura, D. 1971. Right hemisphere specialization for depth perception reflected in visual field differences. Nature, 231, 394-395.

Efron, R. 1963a. The effect of handedness on the perception of simultaneity and temporal order. Brain, 86, 261-284.

Efron, R. 1963b. The effect of stimulus intensity on the perception of simultaneity in right- and left-handed subjects. Brain, 86, 285-294.

Ettlinger, G. 1956. Sensory deficits in visual agnosia. Journal of Neurology, Neurosurgery and Psychiatry, 19, 297-307.

Ettlinger, G., Jackson, C. V., & Zangwill, O. L. 1956. Cerebral dominance in sinistrals. Brain, 79, 569-588.

Ettlinger, G., Warrington, E., & Zangwill, O. L. 1957. A further study of visual spatial agnosia. Brain, 80, 335-361.

Exner, S. 1875. Neber das Sehen von Bewegungen und die Theorie das zusammengesetzen Auges. Sitzungsberichte Akademie Wissenschaft Wien, 72, 156-190.

Fernberger, S. W. 1919. New phenomena of apparent visual movement. American Journal of Psychology, 46, 309-314.

Filbey, R. A., & Gazzaniga, M. S. 1969. Splitting the normal brain with reaction time. Psychonomic Science, 17, 335-336.

Fontenot, D. J., & Benton, A. L. 1972. Perception of direction in the right and left visual fields. Neuropsychologia, 10, 447-452.

Franco, L., & Sperry, R. W. 1977. Hemisphere lateralisation for cognitive processing of geometry. Neuropsychologia, 15, 107-114.

Freud, S. 1891. Zur auffassung der Aphasien, eine Kritische Studie, Leipzig, Franz Deuticke.

Frisby, J. P. 1972. Real and apparent movement--same or different mechanisms? Vision Research, 12, 1051-1055.

Gazzaniga, M. S. 1963. Effects of commisurotomy on a preoperatively learned visual discrimination. Experimental Neurology, 8, 14-18.

Gazzaniga, M. S. 1970. The bisected brain. Appleton-Century- Crofts, New York.

Gazzaniga, M. S., Bogen, J. E., & Sperry, R. W. 1965. Observations on visual perception after disconnection of the cerebral hemispheres in man. Brain, 88, 221-236.

Gazzaniga, M. S., & Hillyard, S. A. 1971. Language and speech capacity of the right hemisphere. Neuropsychologia, 9, 273-280.

Gazzaniga, M. S. & Sperry, R. W. 1967. Language after section of the cerebral commissures. Brain, 90, 131-138.

Gengerelli, J. A. 1948. Apparent movement in relation to homonymus and hetronyumous stimulation of the cerebral hemispheres. Journal of Experimental Psychology, 38, 592-599.

Gibson, J. J. 1950. The perception of the visual world. Houghton Mifflin.

Gibson, J. J. 1954. The visual perception of objective and subjective movement. Psychological Review, 61, 304-314.

Gibson, J. J. 1958. Visually controlled locomotion and visual orientation in animals. British Journal of Psychology, 49, 182-194.

Gibson, J. J. 1961. Ecological optics. Vision Research, 1, 253-262.

Gibson, J. J. 1966. The senses considered as perceptual systems. Houghton Mifflin: Boston.

Goldberg, E., Vaughan, H. G., & Gerstman, L. J. 1978. Nonverbal descriptive systems and hemispheric asymmetry: Shape versus texture discrimination. Brain and Language, 5, 249-257.

Gowers, W. R. 1888. A Manual of Diseases of the Nervous System, Ed. 1, London, A. and G. Churchill, Vol. 2, 102-117.

Gregory, R. L. 1966. Eye and brain: The psychology of seeing. World University Library, Weidenfeld & Nicholson.

Hamilton, C. R. 1977. Investigations of perceptual and mnemonic lateralisation in monkeys. In Harnard, S., et al., Lateralisation in the Nervous System. Academic Press.

Hamilton, C. R., & Lund, J. S. 1970. Visual discrimination of movement: Midbrain or Forebrain? Science, 170, 1428-1430.

Hamilton, C. R., Tieman, S. B., & Farrell, W. S. 1974. Cerebral dominance in monkeys? Neuropsychologia, 12, 193-197.

Hamsher, K de S. 1978. Stereopsis and unilateral brain disease. Investigative Opthalmology and Visual Science, 17, 336-343.

Harcum, E. R. 1978. Lateral dominance as a determinant of temporal order of responding. In M. Kinsbourne (Ed.), Asymmetrical function of the brain. Cambridge University Press.

Harris, L. J. 1978. Sex differences in spatial ability: possible environmental, genetic, and neurological factors. In Kinsbourne, M. (Ed.), Asymmetrical function of the brain. Cambridge University Press.

Head, H. 1926. Aphasia and kindred disorders of speech. Cambridge.

Hecaen, H. 1962. Clinical symptomatology in right and left cerebral lesions. In Mountcastle, V. B. (Ed.), Interhemispheric relations and cerebral dominance. Baltimore.

Hecaen, H. 1969. Aphasic, apraxic and agnostic syndromes in right and left hemisphere lesions. In Vinken, P. J., & Bruyn, G.W. (Eds.), Handbook of Clinical Neurology. Chapter 15, 291-311.

Hecaen, H., & De Ajuriaguerra, J. 1964. Left handedness. Manual preference and cerebral dominance. Grune and Stratton. New York and London.

Hecaen, H., Penfield, W., Bertrand, C., & Malmo, R. 1956. The syndrome of Apractognosia due to lesions of the minor cerebral hemisphere. Archives of Neurology and Psychiatry, 75, 400-434.

Hecaen, H., & Piercy, M. 1956. Paroxysmal dysphasia and the problem of cerebral dominance. Journal of Neurology, Neurosurgery, and Psychiatry, 19, 194-201.

Heron, W. 1957. Perception as a function of retinal locus and attention. American Journal of Psychology, 80, 38-48.

Hines, D. 1972. Bilateral tachistoscopic recognitions of verbal and non verbal stimuli. Cortex, 8, 315-322.

Hines, D. 1975. Independent functioning of the two cerebral hemispheres for recognizing bilaterally presented tachistoscopic visual-half-field stimuli. Cortex, 11, 132-143.

Hines, D. 1978. Visual information processing in the left and right hemispheres. Neuropsychologia, 16, 593-600.

Holmes, G. 1919. Disturbances of visual space perception. British Medical Journal, 2, 230-233.

Hubel, D. H. 1959. Single unit activity in striate cortex of unrestrained cats. Journal of Physiology, 147, 226-238.

Hubel, D. H. & Wiesel, T. N. 1959. Receptive fields of single neurons in the cat's striate cortex. Journal of Physiology, 148, 574-591.

Hubel, D. H., & Wiesel, T. N. 1960. Receptive fields of optic nerve fibres in the spider monkey. Journal of Physiology, 154, 572-580.

Hubel, D. H., & Wiesel, T. N. 1961. Integrative action in the cat's lateral geniculate body. Journal of Physiology, 155, 385-398.

Hubel, D. H., & Wiesel, T. N. 1962. Receptive fields, binocular interaction and functional architecture in the cat's visual cortex. Journal of Physiology, 160, 106-154.

Hubel, D. H., & Wiesel, T. N. 1968. Receptive fields and functional archetecture of monkey striate cortex. Journal of Physiology, 195, 215-243.

Jackson, J. H. 1868. Defect of intellectual expression (aphasia) with left hemiplegia. Lancet, 1, 457.

Jackson, J. H. 1932. Selected writings of John Hughlings Jackson. Ed. Taylor, J. Vol. 2. London, Hodder and Stoughton.

Jasper, H. H. 1932. A laboratory study of diagnostic indices of bilateral neuro-muscular organisation in stutterers and normal speakers. Psychological Monograph, 43, 72-174.

Jasper, H. H., & Raney, E. T. 1937. The phi test of lateral dominance. American Journal of Psychology, 49, 450-457.

Jeeves, M. A. 1972. Hemisphere differences in response rates to visual stimuli in children. Psychonomic Science, 27, 201-203.

Jeeves, M. A., & Dixon, N. F. 1970. Hemisphere differences in response rates to visual stimuli. Psychonomic Science, 20, 249-251.

Julesz, B. 1971. Foundations of cyclopean perception. University of Chicago Press.

Kahneman, D. 1967. An onset-onset law for one case of apparent motion and metacontrast. Perception and Psychophysics, 2, 577-584.

Kelly, D. H., & Savoie, R. E. 1973. A study of sine-wave contrast sensitivity by two psychophysical methods. Perception and Psychophysics, 14, 313-138.

Kimura, D. 1961a. Some effects of tempural lobe damage on auditory perception. Canadian Journal of Psychology, 15, 156-165.

Kimura, D. 1961b. Cerebral dominance and the perception of verbal stimuli. Canadian Journal of Psychology, 15, 166-171.

Kimura, D. 1963. Right temporal lobe damage. Archives of Neurology, 8, 264-271.

Kimura, D. 1963. Speech lateralisation in young children as determined by an auditory test. Journal of Comparative Physiology and Psychology, 56, 899-902.

Kimura, D. 1964. Left-right differences in the perception of melodies. Quarterly Journal of Experimental Psychology, 14, 355-358.

Kimura, D. 1966. Dual functional asymmetry of the brain in visual perception. Neuropsychologia, 14, 275-285.

Kimura, D. 1967. Functional asymmetry of the brain in dichotic listening. Cortex, 3, 163-178.

Kimura, D. 1969. Spatial localisation in the left and right visual fields. Canadian Journal of Psychology, 23, 445-458.

Kimura, D., & Durnford, M. 1974. Normal studies on the function of the right hemisphere in vision. In Dimond, S. J. & Beaumont, J. G. (Eds.), Hemisphere function in the human brain. Paul Elek Ltd.

Kinsbourne, M. 1970. The cerebral basis of lateral asymmetries in attention. Acta Psychologia, 33, 193-201.

Kleist, K. 1912. Der gang und der gegenwurtige Stand der Apraxie-Forschung. Ergebn. Neurol. Psychiat., 1, 342-452.

Knox, C., & Kimura, D. 1970. Cerebral processing of nonverbal sounds in boys and girls. Neuropsychologia, 8, 227-237.

Kolers, P. A. 1963. Some differences between real and apparent movement. Vision Research, 3, 191-206.

Kolers, P. A. 1964. The illusion of movement. Scientific American, 211(4), 98-106.

Kolers, P. A. 1972. Aspects of motion perception. Pergamon Press.

Korte, A. 1915. Kinematoskopische untersuchungen. Zeitschrift fur Psychologie, 72, 193-296.

Kuffler, S. W. 1953. Discharge patterns and functional organisation of mammalian retina. Journal of Neurophysiology, 16, 37-68.

LaGrone, C. W., Jr. 1942. An experimental study of the relationship of peripheral perception to factors in reading. Journal of Experimental Education, 11, 37-49.

Lake, D. A., & Bryden, M. P. 1976. Handedness and sex differences in hemisphere asymmetry. Brain and Language, 8, 266-282.

Lehmann, D., & Walchli, P. 1975. Depth perception and the location of brain lesions. Journal of Neurology, 209, 157-164.

Lenneberg, E. H. 1963. Speech development: Its anatomical and physiological concommitants. In Carterette, E. R. (Ed.), Brain Function, Vol. 3. University of California Press.

Lettvin, J. Y., Maturana, H. R., McCulloch, W. S., & Pitts, W. H. 1958. What the frog's eye tells the frog's brain. Proceedings of the Institute of Radio Engineers, 47, 1940-1951.

Levinson, E., & Sekuler, R. 1975. The independence of channels in human vision selective for direction of movement. Journal of Physiology, 250, 347-366.

Levinson, E., & Sekuler, R. 1976. Adaptation alters perceived direction of motion. Vision Research, 16, 779-781.

Levy, J., & Trevarthen, C. 1977. Perceptual, semantic and phonetic aspects of elementary language processes in split-brain patients. Brain, 100, 105-118.

Levy, J., Trevarthen, C., & Sperry, R. W. 1972. Perception of bilateral chimeric figures following hemispheric deconnection. Brain, 95, 61-78.

Leipmann, H. 1900. Das Krankheitsbild der Apraxie (motorische asymbolie). Monatsschrift fur Psychiatrie und Neurologie, 8, 182-197.

Luria, A. W. 1973. The working brain. Penguin Books.

Macewen, W. 1893. Pyogenic infective diseases of the brain and spinal cord: Meningitis, abscess of brain, infective sinus thrombosis. Glasgow, J. Maclehose & Sons.

McFie, J., Piercy, M. F., & Zangwill, O. L. 1950. Visual-spatial agnosia associated with lesions of the right cerebral hemisphere. Brain, 73, 167-190.

McFie, J., & Zangwill, O. L. 1960. Visual constructive disabilities associated with lesions of the left cerebral hemisphere. Brain, 83, 243-260.

McKeever, W. F., Gill, K. M., & Van Deventer, A. D. 1975. Letter versus dot stimuli as tools for splitting the normal brain with reaction time. Quarterly Journal of Experimental Psychology, 27, 363-373.

McGlone, J., & Davidson, W. 1963. The relation between cerebral speech laterality and spatial ability with special reference to sex and hand preference. Neuropsychologia, 11, 105-113.

McKeever, W. F., & Huling, M. D. 1970. Right hemispheric superiority in graphic reproduction of briefly viewed dot figures. Perceptual and Motor Skills, 31, 201-202.

McKeever, W. F., & Huling, M. D. 1971a. Lateral dominance in tachistoscopic word recognition performances obtained with simultaneous bilateral input. Neuropsychologia, 9, 15-20.

McKeever, W. R., & Huling, M. D. 1971b. Bilateral tachistoscopic word recognition as a function of hemisphere stimulated and inter-hemispheric transfer time. Neuropsychologia, 9, 281-288.

McKeever, W. F., & Suberi, M. 1974. Parallel but temporally displaced visual half field metacontrast functions. Quarterly Journal of Experimental Psychology, 26, 258-265.

McKeever, W. R., Suberi, M., & Van Deventer, A. D. 1972. Fixation controll in tachistoscopic studies of laterality effects: Comment and data relevant to Hines' experiment. Cortex, 8, 473-478.

Mackenzie, A. 1971. On the relation between apparent motion and visual masking. Unpublished B.S. thesis submitted to Edinburgh University.

McKinney, J. P. 1963. Disappearance of lumenous designs. Science, 140, 403-404.

McKinney, J. P. 1967. Handedness, eyedness and perceptual stability of the left and right visual fields. Neuropsychologia, 5, 338-344.

McKinney, J. P. 1966. Lateral asymmetry in the stability of the visual field. Psychonomic Science, 5, 175-176.

Maddess, R. J., Rosenblood, L. K., & Goldwater, B. C. 1973. An improved technique for monitoring fixation in tachistoscopic tasks. Quarterly Journal of Experimental Psychology, 25, 398-403.

Maturana, H. R., Lettvin, J. Y., McCulloch, W. S., & Pitts, W. H. 1960. Anatomy and physiology of vision in the frog (Rana pipens). Journal of General Physiology, 43, Supp. 2, 129-175.

Meyer, O. 1900. Ein und doppelsutige homonyme Hemianopsie mit Unentiungstorungen. Monatsschrift fur Psychiatrie und Neurologie.

Mills, C. K. 1898. The nervous system and its diseases. Philadelphia, J. B. Lippincott Company.

Milner, B. 1958. Psychological defects produced by temporal lobe excision. Research Publications of the Association for Research in Nervous and Mental Disease, 36, 244-257.

Milner, B., Branch, C., & Rasmussen, T. 1963. Observations on cerebral dominance. In DeReuck, A. V. S., & O'Connor, M. (Eds.), Ciba Foundation Symposium on Disorders of Language.

Mishkin, M., & Forgays, D. G. 1952. Word recognition as a function of retinal locus. Journal of Experimental Psychology, 43, 43-48.

Mowbray, G. H., & Durr, L. B. 1964. Visual masking. Nature, 201, 277-278.

Nebes, R. D. 1971. Superiority of the minor hemisphere in commissurotomized man for the perception of part-whole relations. Cortex, 7, 333-349.

Neuhaus, W. 1930. Experimentelle Unterschung der Schienbewegung. Archiv. fur die gesamte Psychologie, 75, 315-458.

Nielsen, J. M. 1937. Unilateral cerebral dominance as related to mind blindness. Archives of Neurology and Psychiatry, 88, 108-135.

Oldfield, R. C. 1969. Handedness in musicians. British Journal of Psychology, 60, 91-99.

Oscar-Berman, M., Blumstein, S., & DeLuca, D. 1976. Iconic recognition of musical symbols in the lateral visual fields. Cortex, 12, 241-248.

Oscar-Berman, M., Goodglass, H., & Gorenstein-Cherlow, D. 1973. Perceptual laterality and iconic recognition of visual materials by Korsakoff patients and normal adults. Journal of Comparative and Physiological Psychology, 82, 316-321.

Orlansky, J. 1940. The effect of similarity and difference in form on apparent visual movement. Archives of Psychology, 246.

Paterson, A., & Zangwill, O. L. 1944. Disorders of visual space perception associated with lesions of the right cerebral hemisphere. Brain, 67, 331-358.

Paterson, A., & Zangwill, O. L. 1945. A case of topographical disorientation associated with a unilateral cerebral lesion. Brain, 68, 188-212.

Piercy, M., Hecaen, H., & De Ajuriaguerra. 1960. Constructional apraxia associated with unilateral cerebral lesions --left and right sided cases compared. Brain, 83, 225-242.

Piercy, M., & Smyth, V. O. G. 1962. Right hemisphere dominance for certain non verbal intellectual skills. Brain, 85, 775-790.

Poffenberger, A. T. 1912. Reaction time to retinal stimulation with special reference to the time lost in conduction through nerve centers. Archives of Psychology, 23, 1-73.

Provens, K. A., & Cunliffe, P. 1972. The reliability of some motor performance tests of handedness. Neuropsychologia, 10, 199-206.

Provens, K. A., Milner, A. D., & Kerr, P. Asymmetry of manual preference and performance. Unpublished manuscript.

Riggs, L. A., Armington, J. C., & Ratliff, F. 1954. Motions of the retinal image during fixation. Journal of the Optical Society of America, 44, 315-321.

Richards, W. 1970. Stereopsis and stereoblendness. Experimental Brain Research, 10, 380-388.

Riddoch, G. 1917. Dissociation of visual perceptions due to occipital injuries, with especial reference to appreication of movement. Brain, 40, 15-57.

Riddoch, G. 1935. Visual disorientation in homonymous half fields. Brain, 58, 376-382.

Roberts, L. 1969. Aphasia, apraxia, and agnosia in abnormal states of cerebral dominance. In Vinken, P. J., & Bruyn, G. W. (Eds.), Handbook of clinical neurology. Volume 4, Chapter 16. North Holland Publishing Co., Amsterdam.

Robinson, D. A. 1965. The mechanics of human smooth persuit eye movement. Journal of Physiology, 180, 569-581.

Rose, R. M., Teller, D. Y., & Rendleman, P. 1970. Statistical properties of staircase estimates. Perception and Psychophysics, 8, 199-204.

Rothstein, T. B., & Sacks, J. G. 1972. Defective stereopsis in lesions of the parietal lobe. American Journal of Opthalmology, 93, 281-284.

Saslow, M. G. 1967. Latency for saccadic eye movement. Journal of the Optical Society of America, 57, 1030-1033.

Satz, P., Achenbach, K., & Fennel, E. 1967. Correlations between assessed manual laterality and predicted speech laterality in a normal population. Neuropsychologia, 5, 295-310.

Schiller, P. H., & Wiener, M. 1963. Monoptic and dichoptic visual masking. Journal of Experimental Psychology, 66, 386-393.

Sekuler, R. W., & Ganz, L. 1963. Aftereffect of seen motion with a stabilized retinal image. Science, 139, 419-420.

Sekuler, R. W., & Levinson, E. 1977. The perception of moving targets. Scientific American, January, 60-73.

Simon, J. R. 1969. Reactions towards the source of stimulation. Journal of Experimental Psychology, 81, 174-176.

Smith, M. C., & Schiller, P. H. 1966. Foreward and backward masking: A comparison. Canadian Journal of Psychology, 20, 337-342.

Sperry, R. W. 1968. Mental unity following surgical disconnection of the cerebral hemispheres. The Harvey Lectures No. 62, 293-323. Academic Press.

Steinig, K. 1929. Untersuchungen uber die Wharnehmung der Bewegung Durch das Auge. Zeitschrift fur Psychologie, 109, 291-336.

Stevens, H. C. 1908a. Peculiarities of peripheral vision. Psychological Review, 15, 69-93.

Stevens, H. C. 1908b. Peculiarities of peripheral vision. II. The perception of motion by the peripheral retina. Psychological Review, 15, 373-390.

Stevens, H. C., & Ducasse, C. J. 1912. The retina and righthandedness. Psychological Review, 19, 1-31.

Terrace, H. S. 1959. The effects of retinal locus and attention on the perception of words. Journal of Experimental Psychology, 58, 382-385.

Trevarthen, C., & Sperry, R. W. 1973. Perceptual unity of the ambient visual field in human commissurotomy patients. Brain, 96, 547-570.

Trevarthen, C. B., & Tursky, B. 1969. Recording horizontal rotations of head and eyes in spontaneous shifts of gaze. Behaviour Research Methods and Instrumentation, 1, 291-293.

Turvey, M. T. 1973. On peripheral and central processes of vision. Psychological Review, 80, 1-52.

Umlita, C., Bagnara, S., & Simon, F. 1978. Laterality effects for simple and complex geometrical figures, and nonsense patterns. Neuropsychologia, 16, 43-49.

Wada, J., & Rasmussen, T. 1960. Intra-cartoid injection of sodium amytal for the lateralisation of cerebral speech dominance. Journal of Neurosurgery, 17, 266-282.

Warrington, E. K., & James, M. 1967. Disorders of visual perception in patients with localised cerebral lesions. Neuropsychologia, 5, 253-266.

Warrington, E. K., James, M., & Kinsbourne, M. 1966. Drawing disability in relation to laterality of cerebral lesion. Brain, 89, 53-82.

Weinstein, S. 1962. Differences in effects of brain wounds inplicating right or left hemispheres. In Mountcastle, V. B., (Ed.), Interhemispheric relations and cerebral dominance. Baltimore.

Weisstein, N., & Growney, R. L. 1969. Apparent movement and metacontrast: A note on Kahneman's formulation. Perception and Psychophysics, 5, 321-328.

Wernicke, C. 1874. Der aphasische symptomencomplex. Breslau, Max Cohn and Weigert.

Wertheimer, M. 1912. Experimentelle studien uber das Schen von Bewegung. Zeitschrift fur Psychologie, 61, 161-265. Translated in Shipley, T. (Ed.), Classics in Psychology, 1961. New York: Philosophical Library.

Westheimer, W. 1954. Mechanism of saccadic eye movements. Archives of Ophthalmology, 52, 710-724.

Wetherill, G. B., & Levitt, H. 1965. Sequential estimation of points on a psychometric function. British Journal of Mathematical and Statistical Psychology, 18, 1-10.

White, A. M., & Dallenbach, K. M. 1932. Position vs. intensity as a determinant of the attention of left-handed observers. American Journal of Psychology, 44, 175-179.

White, M. J. 1969. Laterality differences in perception. Psychological Bulletin, 72, 387-405.

White, M. J. 1971. Visual hemifield differences in the perception of letters and contour orientation. Canadian Journal of Psychology, 25, 207-212.

White, M. J. 1972. Hemispheric asymmetries in tachistoscopic information-processing. British Journal of Psychology, 63, 4, 497-508.

White, M. J. 1973. Does cerebral dominance offer a sufficient explanation for laterality differences in tachistoscopic recognition? Perceptual and Motor Skills, 36(2), 478-485.

White, M. J., & White, K. G. 1975. Parallel-serial processing and hemispheric function. Neuropsychologia, 13, 377-381.

Witelson, S. F. 1975. Age and sex differences in the development of right hemispheric specialization for spatial processing as reflected in a dichotomous tactual stimulation task. Paper presented to Society for Research in Child Development, Denver.

Wyke, M., & Ettlinger, G. 1961. Efficiency of recognition in left and right visual fields. Archives of Neurology, 5, 95-101.

Zaidel, E. 1977. Unilateral auditory language comprehension on the token test following cerebral commissurotomy and hemispherectomy. Neuropsychologia, 15, 1-18.

Zurif, E. B., & Bryden, M. P. 1969. Familial handedness and left right differences in auditory and visual perception. Neuropsychologia, 7, 179-187.

ADDITIONAL REFERENCES

Anstis, S. M. 1978. Apparent movement. In Held, R., Leibowitz, H. W., and Teuber, H. W. (Eds.), Handbook of Sensory Physiology. V. 8. Perception. Springer-Verlag.

Berlucchi, G., Heron, W., Hyman, R., Rizzolatti,G., and Umilta, C. 1971. Simple reaction times of ipsilateral and contralateral hand to lateralised visual stimuli. Brain, 94, 419-430

Biederman-Thorson, M., Thorson, J. and Lange, G. D. 1971. Apparent movement due to closely spaced sequentially flashed dots in the peripheral field of vision. Vision Research, 11, 899-903.

Braddick, O. 1980. Low-level and high-level processes in apparent motion. Phil. Trans. R. Soc. London. B. 290, 137-151.

Breitmeyer, B., Love, R., and Wepman, B. 1974. Contour suppression during stroboscopic motion and metacontrast. Vision Research, 14, 1451-1456.

Cohen, G. 1973. Hemispheric differences in serial versus parallel processing. Journal of Experimental Psychology. 97, 3, 349-356.

Efron, R., and Lee, D. N. 1971. The visual persistance of a moving stroboscopically illuminated object. American Journal of Psychology, 84, 3, 365-375.

Frisby, J. P. 1972a. The effect of stimulus orientation on the phi phenomenon. Vision Research, 12, 1145-1166.

Grusser, O. J., and Grusser-Cornehls, U. 1973. Neuronal mechanisms in visual movement perception and some psychophysical and behavioural correlations. In Jung, R. (ed.), Handbook of Sensory Physiology. Vol. VII/3A: Central Processing of Information. New York. Springer-Verlag.

Kaufman, L., Cryulnik, I., Klapowitz, G., and Stoff, D. 1971. The complimentarity of Apparent and Real Motion. Psychol. Forsch. 34, 343-348.

Kinsbourne, M. 1973. The Control of Attention by Interaction Between the Cerebral Hemispheres. In Kornblum, S.(ed.), Attention and Performance. 4. Academic Press.

Kocel, K. M. 1977. Cognitive abilities: Handedness, Familial Sinistrality, and Sex. In Dimond, S. J. and Blizard, D. A. (Eds.), Evolution and Lateralisation of the Brain. New York Academy of Sciences.

Levy, J. 1974. Psychobiological Implications of Bilateral Asymmetry. In Dimond, S. J. and Beaumont, J. G. (Eds.), Hemispheric Function in the Human Brain. Paul Elek.

Lichtenstein, M. 1963. Spatio-Temporal Factors in Cessation of Smooth Apparent Motion. Journal of the Optical Society of America, 53, 304-306.

Milner, B. and Taylor, L. 1972. Right hemisphere superiority in tactile pattern-recognition after cerebral commissurotomy: evidence for nonverbal memory. Neuropsychologia, 10, 1-15.

Moscovitch, M. 1973. Language and the cerebral hemispheres: Reaction time studies and their implications for models of cerebral dominance. In Pilner et al. (eds.), Communication and Affect - Language and Thought. Academic Press.

Moscovitch, M. 1979. Information processing and the cerebral hemispheres In Gazzaniga, M. (ed.), Handbook of Behavioral Neurobiology, 2. Plenum Press.

Pantle, A. J. 1973. Stroboscopic movement based upon global information in successively presented visual patterns. Journal of the Optical Society of America, 63, 1280A.

Pantle, A. J., Picciano, L. 1976. A multistable display: Evidence for two separate motion systems in human vision. Science, 193, 500-502.

Petersik, J. T. and Pantle, A. J. 1979. Factors controlling the competing sensations produced by a bistable stroboscopic motion display. Vision Research, 19, 143-154.

Ramachandran, V. S., Madhusudhan Rao, V. and Vidyasagar, T. R. 1973. Apparent motion with subjective contours. Vision Research, 13, 1399-1401.

Rasmussen, T. and Milner, B. 1977. The role of early left brain injury in determining lateralisation of cerebral speech functions. In Dimond, S. J. and Blizard, D. A. (Eds.), Evolution and Lateralisation of the Brain. New York Academy of Sciences.

Seamon, J. G. 1974. Coding and retrieval processes and the hemispheres of the brain. In Dimond, S. J. and Beaumont, J. G. (Eds.), Hemisphere function in the human brain. Paul Elek.

Sekuler, R. 1975. Visual motion perception. In Carterette, C. C. and Friedman, M. P. (Eds.), Handbook of Perception. V. 5. Academic Press.

Semmes, J. 1968. Hemispheric specialisation: A possible clue to mechanism. Neuropsychologia, 6, 11-26.

Shepard, R. N. and Judd, S. A. 1976. Perceptual illusion of three dimensional objects. Science, 191, 952-954.

Swanson, J., Ledlow, A. and Kinsbourne, M. 1978. Lateral asymmetries revealed by simple reaction time. In Kinsbourne, M. (Ed.), Asymmetrical function of the brain. Cambridge University Press.

Thorson, J., Lange, G. D. and Biederman-Thorson, M. 1969. Objective measure of the dynamics of a visual movement illusion. Science, 164, 1087-1088.

Townsend, J. T. 1972. Some results concerning the identity of parallel and serial processes. British Journal of Mathematical and Statistical Psychology, 25, 168-199.

Weinstein, S. 1978. Functional cerebral hemispheric asymmetry. In Kinsbourne, M. (ed.), Asymmetrical function of the brain. Cambridge University Press.

APPENDIX A

HANDEDNESS QUESTIONNAIRE

Please answer all questions.

Name _____

Sex _____

Age _____

Date _____

Please circle the appropriate response for each of the following questions, assuming that both hands are free and that any object to be manipulated is equidistant from both hands. Some of the activities may be unfamiliar to you, but try to imaging the situation and answer accordingly. Indicate your degree of preference on the following scale:

-3	-2	-1	0	1	2	3
always with the left	usually the left	more often left than right	no preference	more often right than left	usually the right	always with the right

---

1. To write a letter legibly?

   -3 -2 -1 0 1 2 3

2. To throw a ball to hit a target?

   -3 -2 -1 0 1 2 3

3. To play a game requiring the use of a racket, such as tennis?

   -3 -2 -1 0 1 2 3

4. To hold a match when striking it?

   -3 -2 -1 0 1 2 3

5. To hold scissors to cut paper?

   -3 -2 -1 0 1 2 3

6. To deal playing cards?

-3 -2 -1 0 1 2 3

7. To hammer a nail into wood?

-3 -2 -1 0 1 2 3

8. To hold a toothbrush when cleaning your teeth?

-3 -2 -1 0 1 2 3

9. To draw?

-3 -2 -1 0 1 2 3

10. To hold a screwdriver when fixing screws?

-3 -2 -1 0 1 2 3

11. To stir a cup of tea or coffee?

-3 -2 -1 0 1 2 3

12. To use a bottle opener?

-3 -2 -1 0 1 2 3

13. With which foot do you kick a ball?

-3 -2 -1 0 1 2 3

14. To carry your books?

-3 -2 -1 0 1 2 3

15. Which foot do you put a sock (or shoe) on first?

-3 -2 -1 0 1 2 3

16. To erase something with an eraser?

-3 -2 -1 0 1 2 3

17. Do you suffer from any physical or other handicap which might influence your answer to these questions?

Yes No

18. Is your mother left-handed?

Yes No

19. Is your father left-handed?

    Yes No

20. How many brothers do you have?

    0 1 2 3 4 5 6

    How many of your brothers are left-handed?

    0 1 2 3 4 5 6

21. How many sisters do you have?

    0 1 2 3 4 5 6

    How many of your sisters are left-handed?

    0 1 2 3 4 5 6

22. Have you ever suffered from any speech difficulties?

    If so, please give details:

23. With which eye do you look through a telescope?

    Any other comments:

    (At this point, the subject was asked whether his responses had been mediated by subvocal verbalization.)

APPENDIX B

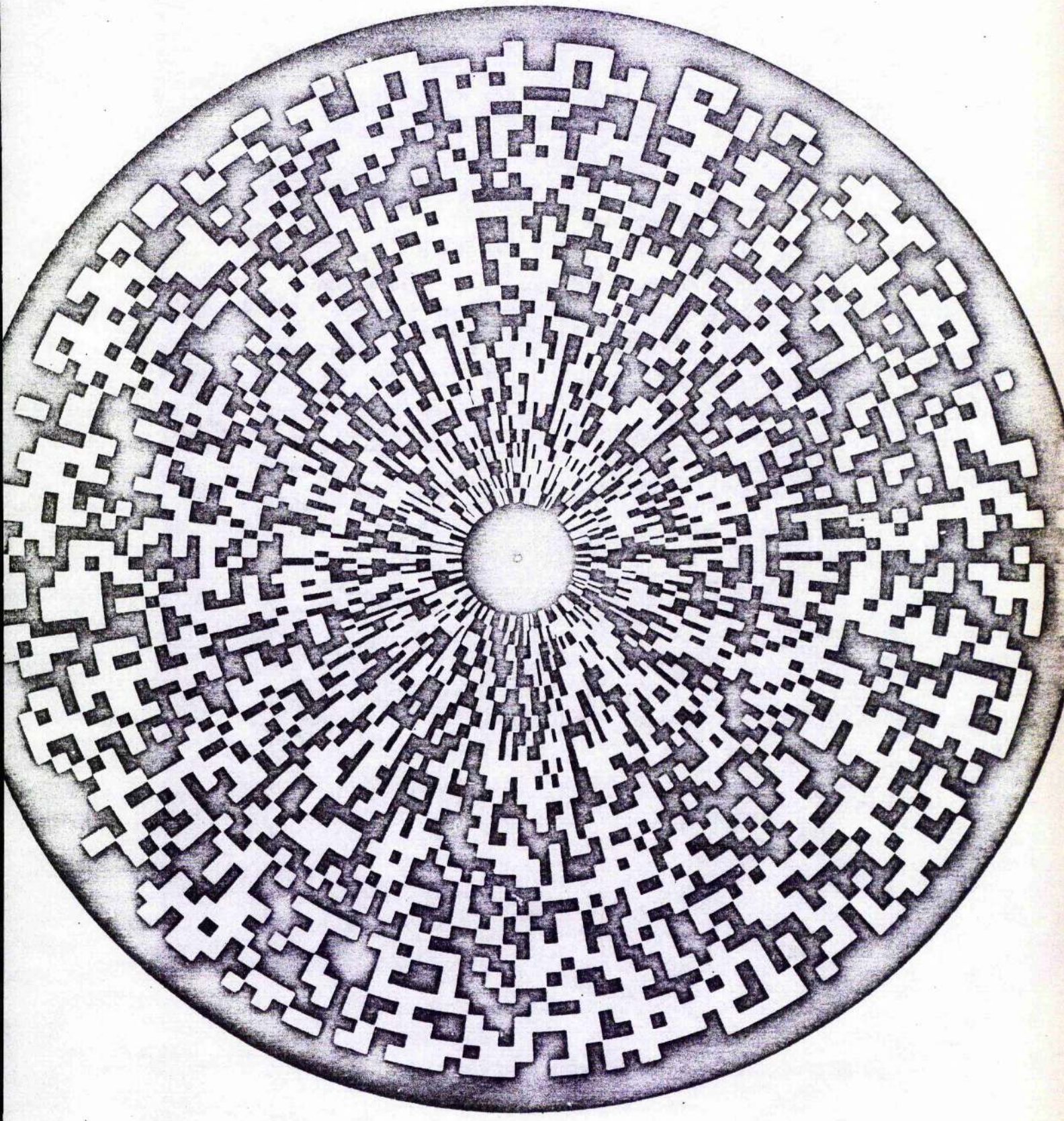


Figure 1. Experiment One Stimulus
(Reduced from 9-7/8 in diameter)

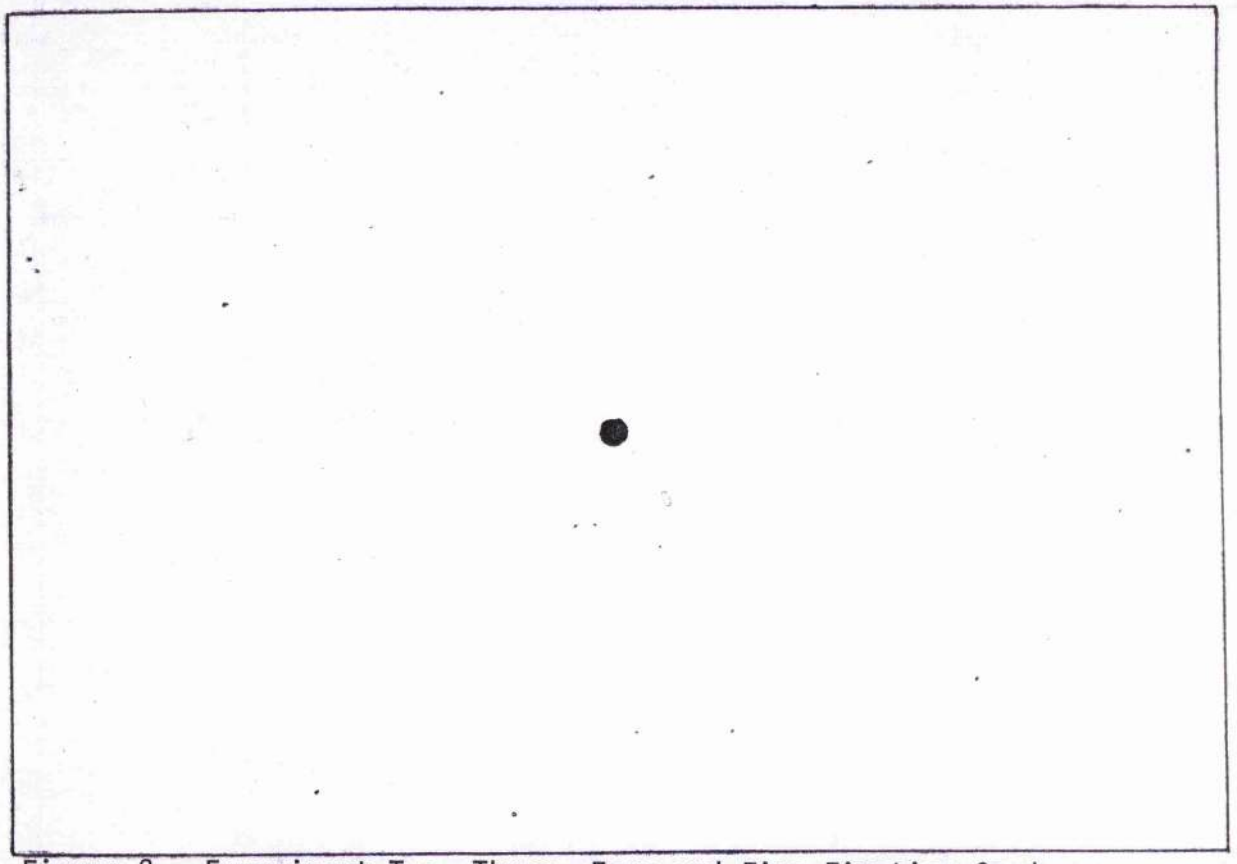


Figure 2. Experiment Two, Three, Four and Five Fixation Card.

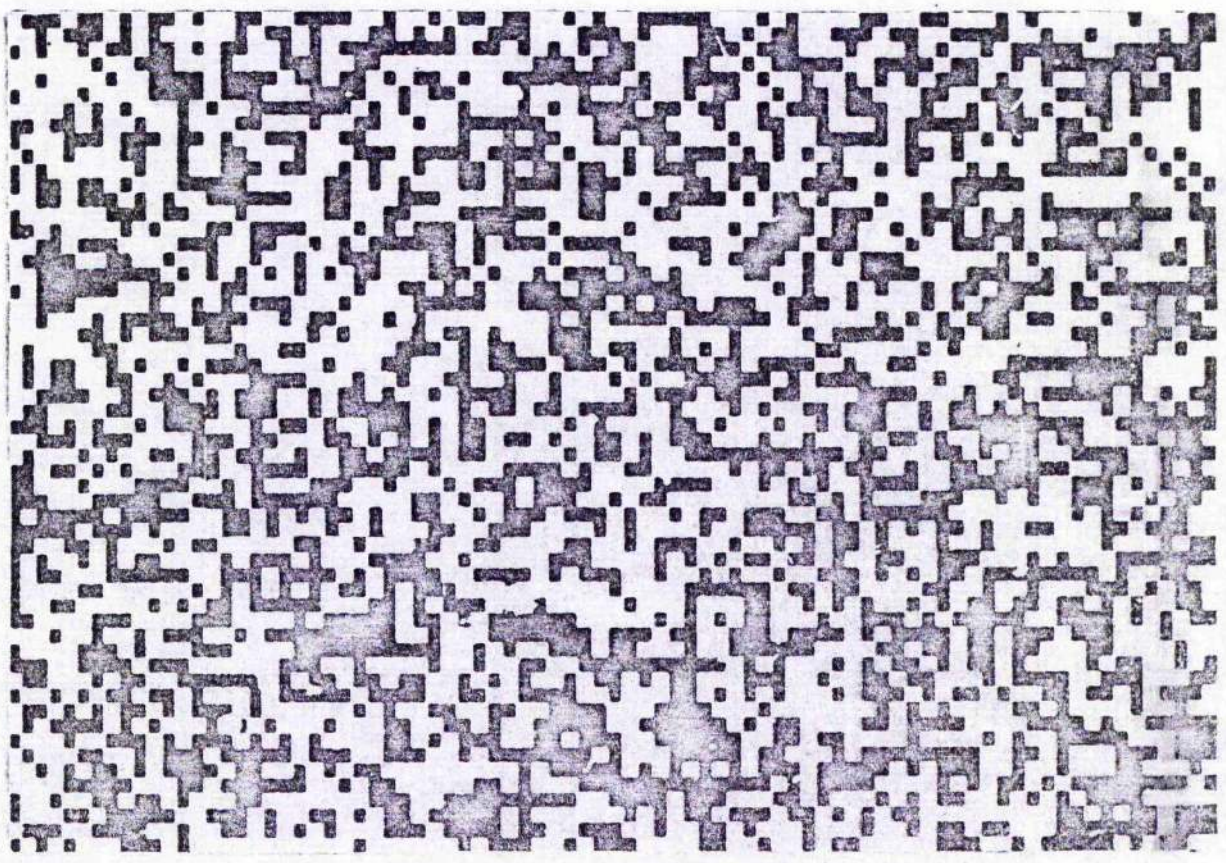


Figure 3. Experiments Two, Three and Four Stimulus Card 1.

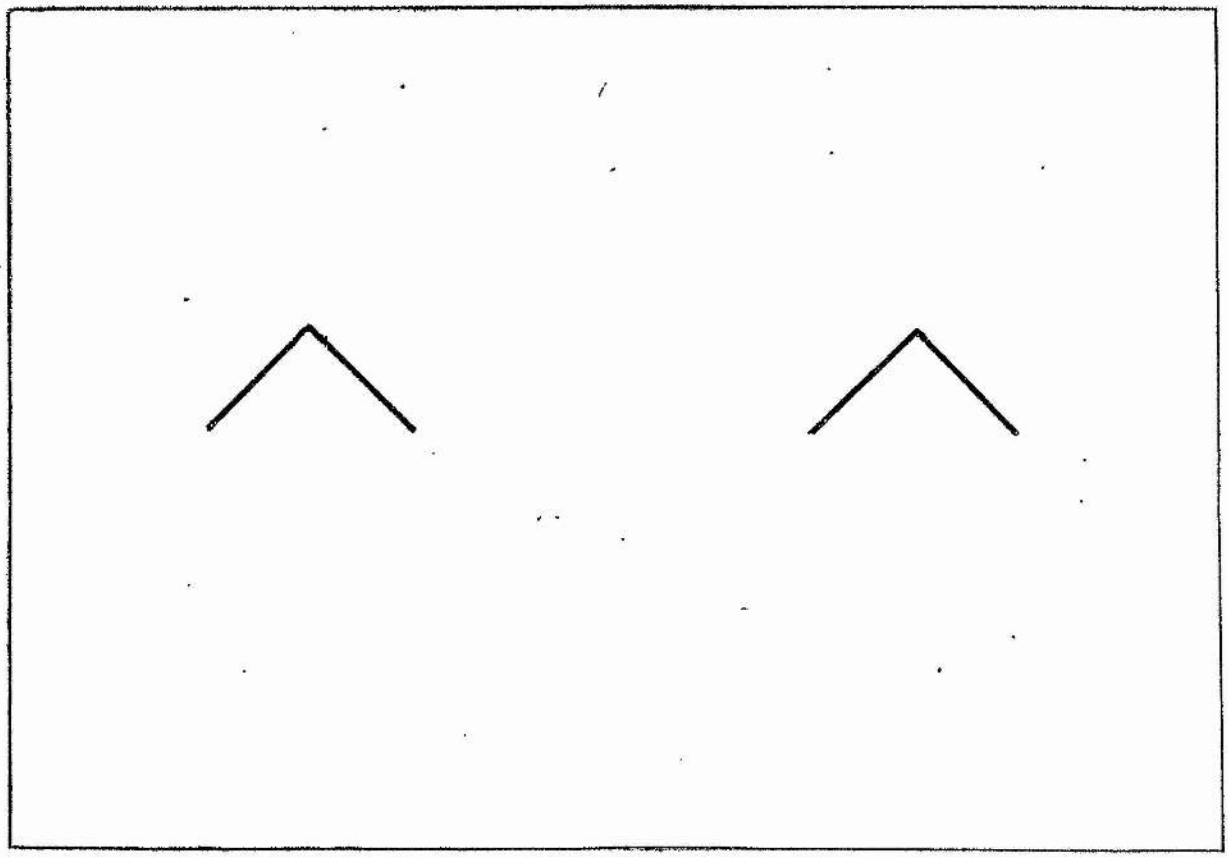


Figure 4. Experiment Five Card 1.

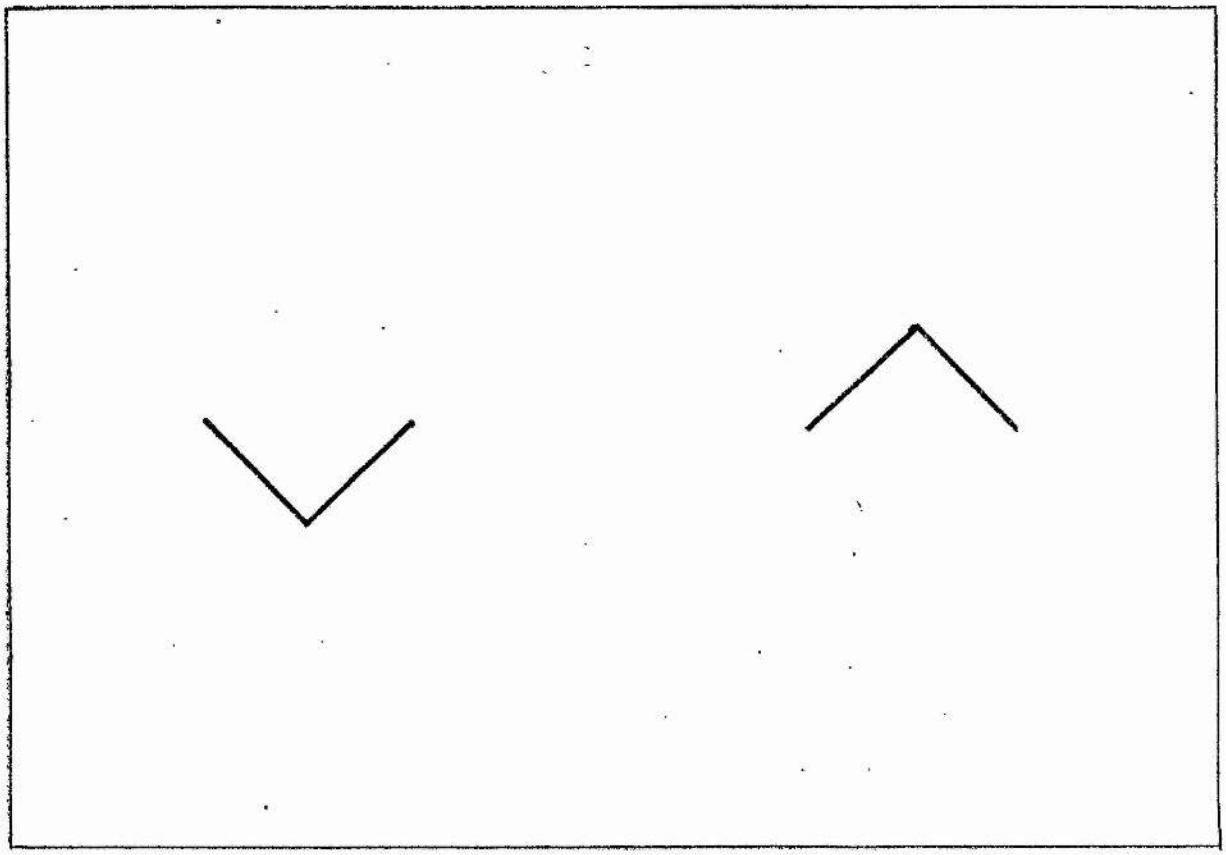


Figure 5. Experiment 5 Card 3.

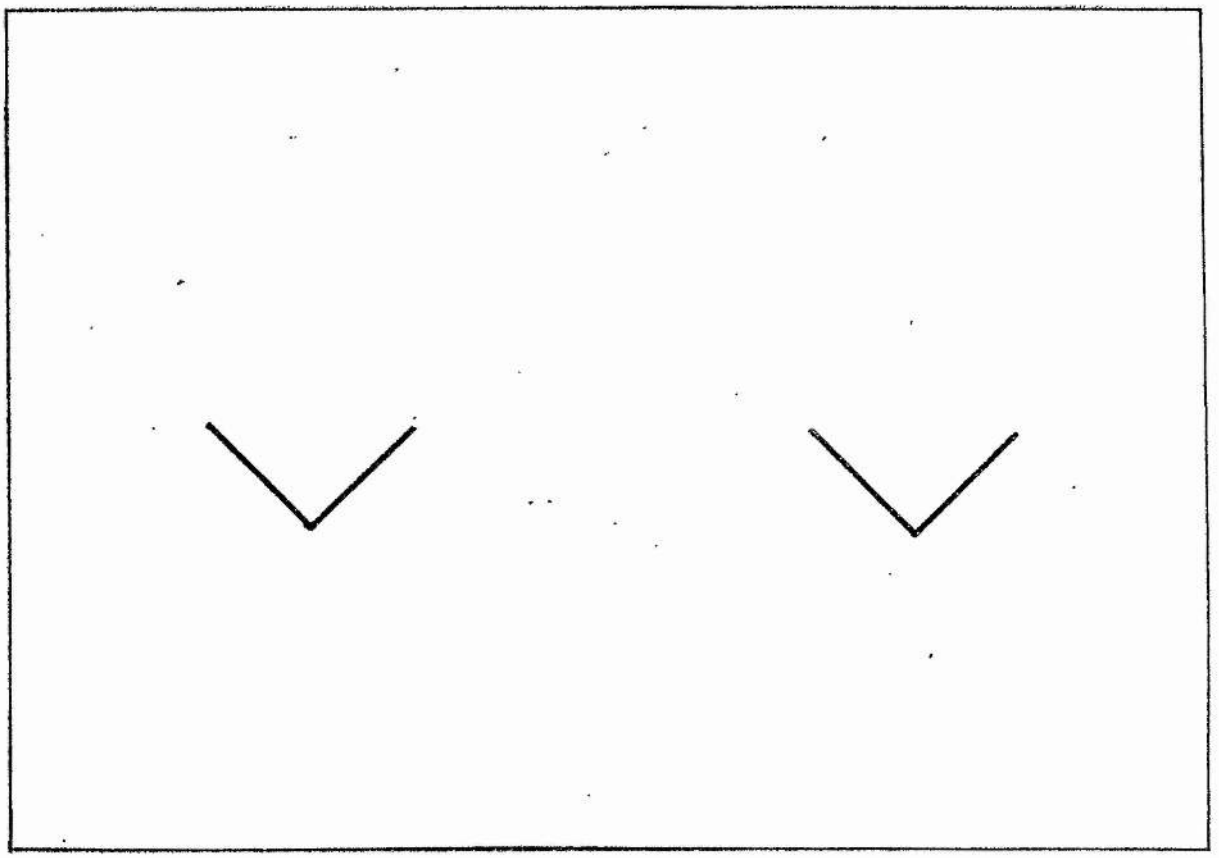


Figure 6. Experiment 5 Card 2.

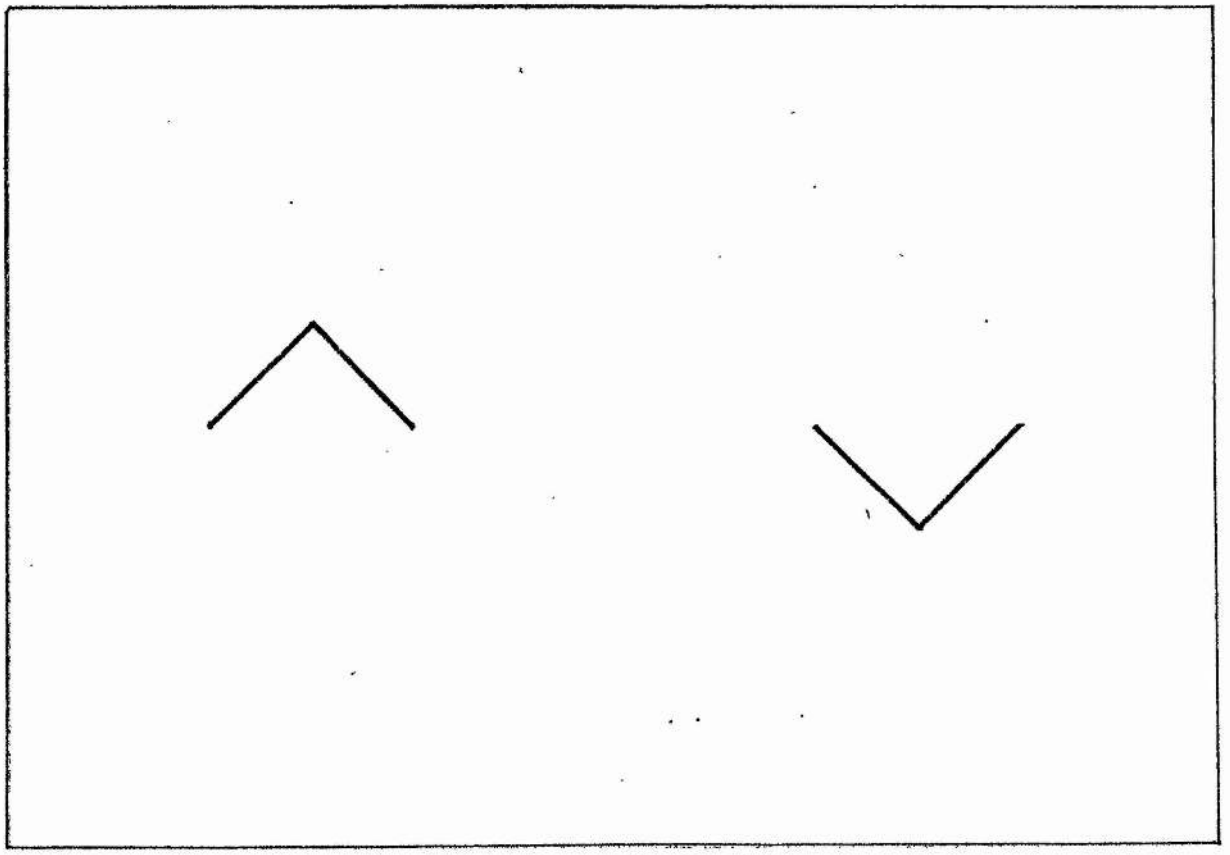


Figure 7. Experiment 5 Card 4.

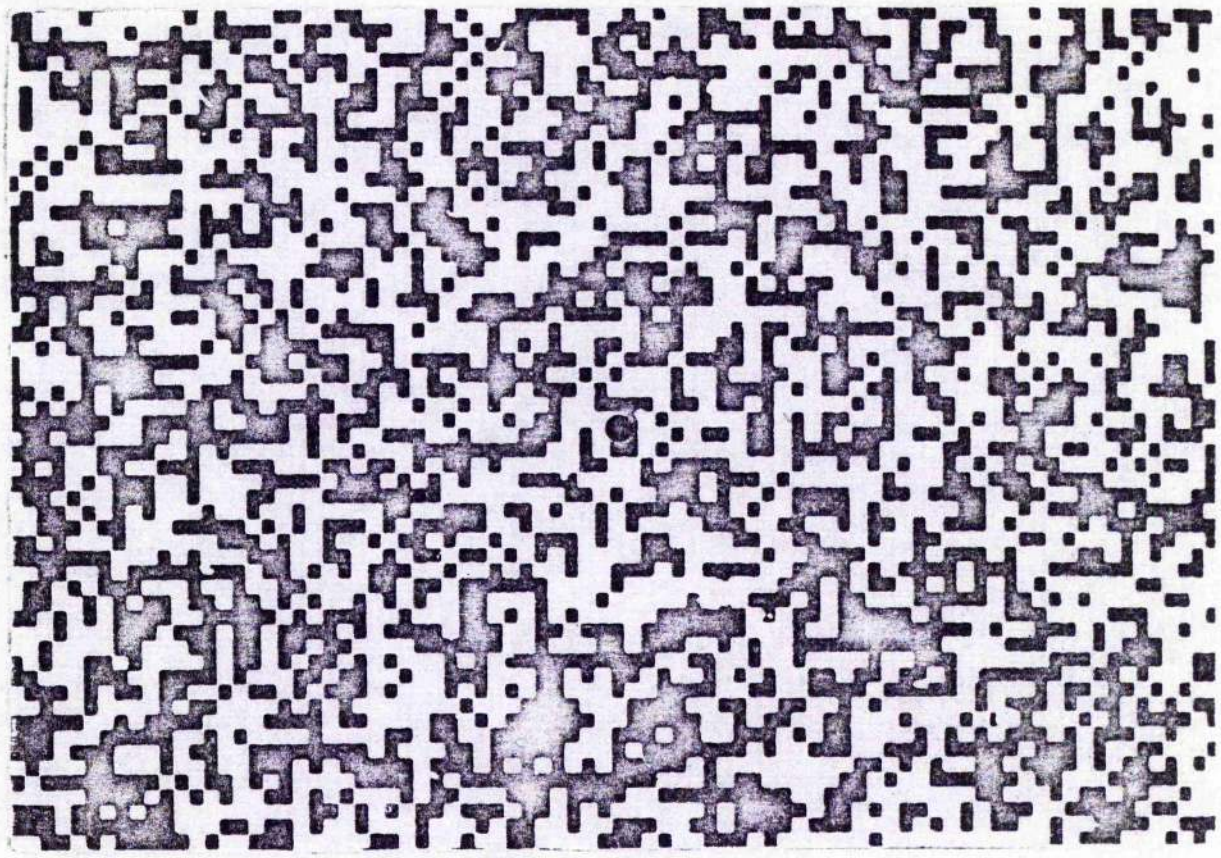


Figure 8. Experiment 6 Fixation Card.

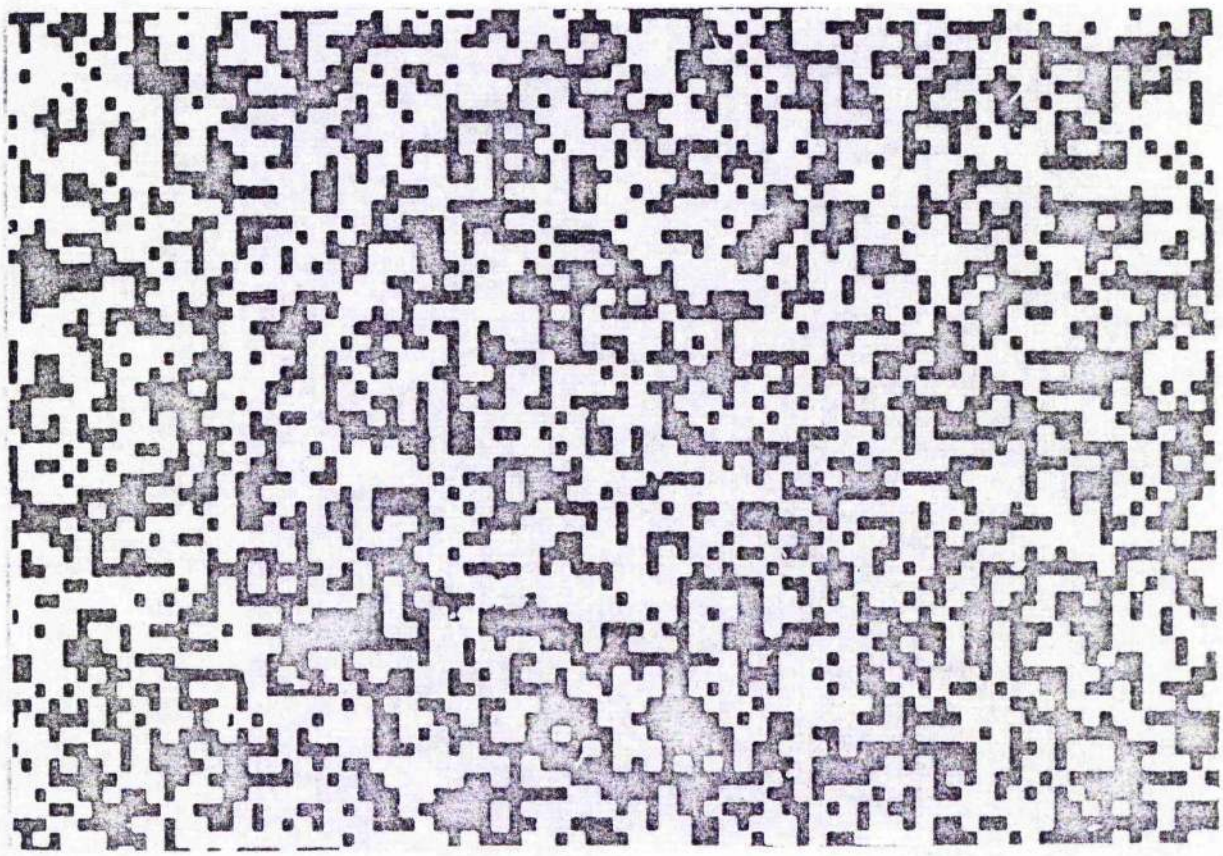


Figure 9. Experiment 6 Card 2.

APPENDIX C

Hemisphere		Left				Right			
Hand		Left		Right		Left		Right	
Subj.	Sex	Trial	Cont.	Trial	Cont.	Trial	Cont.	Trial	Cont.
101	M	1	13.73	2	13.67	1	12.53	2	14.07
102	M	1	16.40	2	16.80	1	12.80	2	19.60
103	M	1	13.53	2	16.60	1	13.93	2	15.53
104	M	1	14.40	2	12.60	1	15.20	2	12.33
105	M	1	16.40	2	15.80	1	16.07	2	16.73
106	M	2	14.87	1	11.93	2	14.13	1	9.87
107	M	2	15.87	1	11.40	2	15.13	1	12.47
108	M	2	18.40	1	13.47	2	16.20	1	13.53
109	M	2	12.67	1	13.47	2	15.27	1	11.40
110	M	2	12.00	1	10.20	2	15.80	1	13.06
111	F	1	16.67	2	14.60	1	10.60	2	14.40
112	F	1	11.07	2	17.87	1	11.33	2	16.67
113	F	1	15.20	2	19.00	1	14.80	2	19.53
114	F	1	16.60	2	15.00	1	15.33	2	15.67
115	F	1	9.73	2	8.33	1	8.67	2	13.40
116	F	2	18.47	1	16.80	2	20.87	1	16.46
117	F	2	11.07	1	13.67	2	15.47	1	12.80
118	F	2	17.93	1	19.00	2	16.07	1	17.80
119	F	2	11.07	1	13.67	2	9.13	1	9.93
120	F	2	17.07	1	16.27	2	16.20	1	11.53
Mean			14.66		14.51		14.28		14.34
SD			2.68		2.83		2.81		2.85

Table 1.

Experiment One. Individual subjects' contrast threshold data.

Hemisphere		Left				Right			
Hand		Left		Right		Left		Right	
Subj.	Sex	Trial	%Cor.	Trial	%Cor.	Trial	%Cor.	Trial	%Cor.
201	M	1	90	2	85	1	85	2	85
202	M	1	90	2	85	1	80	2	75
203	M	1	100	2	85	1	100	2	90
204	M	1	90	2	75	1	90	2	95
205	M	2	70	1	85	2	80	1	90
206	M	2	65	1	55	2	75	1	65
207	M	2	60	1	70	2	90	1	85
208	M	2	100	1	90	2	100	1	85
209	M	1	80	2	90	1	90	2	90
210	M	1	45	2	85	1	100	2	100
211	M	1	95	2	80	1	90	2	100
212	M	1	60	2	85	1	65	2	75
213	M	2	70	1	75	2	95	1	80
214	M	2	100	1	85	2	100	1	80
215	M	2	90	1	95	2	90	1	100
216	M	2	85	1	70	2	100	1	95
Mean			80.63		80.94		89.38		86.88
SD			16.92		9.87		10.31		10.14

Table 2.

Experiment Two data. Individual subjects' percent correct.

Hemisphere		Left				Right			
ISI		a	b	c	d	a	b	c	d
Subj.	Sex								
301	M	75	70	95	95	75	60	75	80
302	M	95	85	95	95	55	75	85	90
303	M	60	75	85	80	70	70	70	90
304	M	45	80	70	100	100	90	100	90
305	F	55	70	75	80	55	55	40	65
306	F	75	45	75	65	75	55	60	65
307	F	85	95	95	95	85	80	80	85
308	F	90	85	85	90	60	60	55	60
309	F	65	75	65	65	60	70	60	65
310	F	45	50	60	65	65	70	60	75
311	F	90	85	95	95	70	70	55	60
312	F	100	95	95	95	60	70	70	70
313	F	70	60	65	95	60	60	55	40
314	F	70	85	90	100	60	70	70	70
315	F	60	40	55	75	60	50	70	80
316	F	60	70	65	75	75	55	70	80
Mean		71.25	72.82	79.06	85.31	67.81	66.88	67.19	72.81
SD		17.08	16.73	14.40	12.97	12.11	10.07	14.14	13.66

Table 3.

Experiment Three data. Individual subjects' percent correct.

Data collapsed across Hands and Trials.

ISIs increase in 1ms steps.

Hemisphere		Left				Right			
Condition		1	2	3	4	1	2	3	4
Subj.	Sex								
401	M	100	100	100	100	100	100	100	100
402	M	100	75	100	100	100	100	100	100
403	M	75	25	25	25	100	50	100	100
404	M	100	100	100	100	100	100	75	75
405	M	75	50	25	25	75	50	100	75
406	M	75	75	50	100	50	25	100	75
407	M	100	75	100	100	100	50	100	50
408	M	100	100	100	100	100	100	100	100
409	F	100	100	100	100	75	75	100	100
410	F	50	50	75	75	50	50	100	75
411	F	75	100	100	100	75	50	100	100
412	F	75	50	100	100	50	50	50	75
413	F	75	50	100	75	75	75	100	100
414	F	100	75	100	75	75	50	100	75
415	F	100	100	100	100	100	50	100	100
416	F	75	75	75	75	75	100	100	75
Mean		85.94	75.00	80.00	71.88	81.25	67.19	89.06	85.94
SD		15.73	24.15	33.67	37.50	19.36	25.36	27.34	15.73

Table 4a.

Experiment Four data. Individual Subjects' percent correct. Trial 1. Data collapsed across Hands. Conditions are the four ISIs.

Hemisphere		Left				Right			
Condition		1	2	3	4	1	2	3	4
Subj.	Sex								
401	M	87.5	62.5	100	100	62.5	62.5	100	75
402	M	87.5	62.5	87.5	75	62.5	62.5	62.5	100
403	M	75	37.5	87.5	50	62.5	62.5	62.5	62.5
404	M	100	75	100	87.5	75	75	62.5	87.5
405	M	75	50	87.5	75	50	25	100	100
406	M	37.5	75	100	75	75	50	87.5	75
407	M	100	100	100	100	62.5	87.5	75	75
408	M	100	75	100	100	75	75	100	87.5
409	F	100	100	100	100	100	87.5	100	100
410	F	75	50	75	87.5	62.5	62.5	87.5	100
411	F	100	87.5	100	100	75	62.5	100	100
412	F	37.5	50	62.5	62.5	62.5	37.5	87.5	87.5
413	F	87.5	62.5	87.5	100	87.5	87.5	75	100
414	F	75	37.5	62.5	87.5	37.5	62.5	62.5	87.5
415	F	100	100	100	100	100	62.5	100	87.5
416	F	100	75	100	100	87.5	75	87.5	100
Mean		83.59	68.75	84.38	81.25	66.72	61.09	84.38	89.06
SD		20.87	20.92	26.02	26.61	23.57	23.24	15.48	11.97

Table 4b.

Experiment Four data. Individual subjects' percent correct. Trial 2. Data collapsed across Hands. Conditions are the four ISIs.

Hemisphere		Left				Right			
Condition		1	2	3	4	1	2	3	4
Subj.	Sex								
401	M	37.5	50	75	87.5	62.5	50	62.5	100
402	M	25	50	100	100	50	62.5	75	75
403	M	75	62.5	62.5	100	75	62.5	87.5	50
404	M	100	50	75	75	50	37.5	87.5	87.5
405	M	87.5	12.5	75	62.5	25	62.5	87.5	75
406	M	62.5	25	87.5	62.5	75	25	87.5	75
407	M	87.5	100	100	100	62.5	75	87.5	87.5
408	M	100	50	87.5	100	62.5	62.5	87.5	87.5
409	F	62.5	75	100	100	87.5	50	62.5	87.5
410	F	50	50	87.5	100	87.5	37.5	100	100
411	F	75	75	100	100	75	62.5	100	100
412	F	50	37.5	62.5	50	62.5	50	75	100
413	F	87.5	62.5	87.5	100	100	62.5	100	87.5
414	F	75	37.5	87.5	87.5	12.5	25	62.5	62.5
415	F	100	87.5	100	100	62.5	62.5	62.5	62.5
416	F	100	100	100	87.5	87.5	75	87.5	100
Mean		73.44	57.81	86.72	88.28	64.84	53.91	82.03	83.59
SD		23.66	24.95	13.28	16.75	22.92	15.63	13.67	15.63

Table 4c.

Experiment Four data . Individual subjects' percent correct. Trial 3. Data collapsed across Hands. Conditions are the four ISIs.

Hemisphere		Left				Right			
ISI		a	b	c	d	a	b	c	d
Subj.	Sex								
501	M	50	75	50	50	0	25	25	25
502	M	50	100	100	50	50	75	75	100
503	M	0	25	50	50	25	50	25	75
504	M	25	75	75	100	25	50	75	100
505	M	100	100	75	75	50	50	25	75
506	M	75	75	100	100	75	75	75	75
507	M	25	75	50	50	50	75	100	50
508	M	0	100	100	100	0	25	75	100
509	F	50	75	100	100	25	50	50	0
510	F	50	50	50	75	75	50	75	25
511	F	25	75	50	100	25	25	75	50
512	F	0	50	75	25	0	75	25	75
513	F	25	75	75	75	0	100	75	75
514	F	25	50	100	100	50	0	75	75
515	F	75	50	75	75	75	25	50	100
516	F	25	50	75	100	50	75	100	50
Mean		37.50	68.75	74.94	78.13	35.94	51.56	62.50	65.63
SD		28.87	21.41	20.60	23.94	27.34	26.57	25.82	30.10

Table 5a.

Experiment Five data. Individual subjects' percent space responses. Trial 1. Data collapsed across Hands. ISIs increase in 10ms steps.

Hemisphere		Left				Right			
ISI		a	b	c	d	a	b	c	d
Subj.	Sex								
501	M	62.5	100	37.5	62.5	0	37.5	0	12.5
502	M	12.5	25	100	87.5	12.5	0	25	87.5
503	M	37.5	37.5	37.5	25	0	62.5	62.5	25
504	M	50	12.5	75	87.5	37.5	25	75	100
505	M	75	75	87.5	87.5	50	75	62.5	50
506	M	87.5	62.5	87.5	87.5	75	100	62.5	75
507	M	25	25	62.5	62.5	25	37.5	75	75
508	M	50	75	87.5	75	0	25	37.5	75
509	F	25	62.5	62.5	62.5	25	0	37.5	50
510	F	12.5	25	87.5	37.5	75	50	75	62.5
511	F	12.5	37.5	37.5	50	0	12.5	50	37.5
512	F	25	37.5	50	25	25	37.5	87.5	87.5
513	F	25	62.5	75	62.5	25	62.5	100	75
514	F	25	25	37.5	62.5	50	25	50	50
515	F	50	62.5	75	50	50	87.5	100	87.5
516	F	0	50	87.5	87.5	12.5	50	62.5	100
Mean		35.94	48.44	67.79	63.28	28.91	42.97	60.16	65.63
SD		24.53	24.10	21.88	21.64	25.30	29.21	26.70	26.02

Table 5b.

Experiment Five data. Individual subjects' percent space responses. Trial 2. Data collapsed across Hands. ISIs increase in 10ms steps.

Hemisphere		Left				Right			
ISI		a	b	c	d	a	b	c	d
Subj.	Sex								
501	M	37.5	75	62.5	75	0	0	0	0
502	M	0	12.5	62.5	100	0	0	25	62.5
503	M	25	25	25	62.5	37.5	12.5	25	25
504	M	12.5	0	50	75	12.5	25	25	100
505	M	100	100	75	75	12.5	50	12.5	25
506	M	50	50	100	87.5	25	50	50	75
507	M	12.5	12.5	62.5	37.5	0	37.5	75	75
508	M	0	37.5	75	100	0	25	25	75
509	F	62.5	37.5	87.5	62.5	12.5	25	37.5	12.5
510	F	12.5	50	75	62.5	25	50	100	75
511	F	50	37.5	37.5	50	12.5	50	50	50
512	F	25	25	37.5	25	37.5	75	75	87.5
513	F	12.5	50	25	50	0	50	75	62.5
514	F	37.5	25	62.5	50	62.5	87.5	25	37.5
515	F	12.5	75	75	87.5	50	87.5	87.5	100
516	F	12.5	25	100	100	12.5	37.5	87.5	75
Mean		28.91	39.84	63.28	68.75	18.13	41.41	48.34	58.59
SD		26.50	26.31	23.48	22.82	19.74	26.89	30.91	30.52

Table 5c.

Experiment Five data. Individual subjects' percent space responses. Trial 3. Data collapsed across Hands. ISIs increase in 10ms steps.

Stimulus duration		1		2		3		4	
Shape		S	D	S	D	S	D	S	D
Subj.	Sex								
601	M	40	100	30	100	60	100	40	90
602	M	100	20	100	90	100	60	100	60
603	M	100	90	90	100	100	90	100	100
604	M	100	30	100	90	100	80	100	60
605	M	60	70	100	70	60	90	60	80
606	M	60	70	70	70	70	50	70	60
607	M	100	70	100	90	100	90	100	80
608	M	100	100	100	100	100	90	100	90
609	F	100	30	90	10	90	60	90	60
610	F	70	100	60	80	70	90	60	80
611	F	100	90	90	80	100	100	100	100
612	F	100	40	100	70	100	30	100	40
613	F	70	70	80	50	90	80	90	50
614	F	70	40	80	80	100	20	100	30
615	F	100	50	100	50	90	50	100	50
616	F	100	100	100	100	100	100	100	100
Mean		85.63	66.88	86.88	76.88	89.38	73.75	88.13	70.63
SD		20.32	28.45	19.73	24.14	15.26	25.53	88.13	22.35

Table 6a.

Experiment Six data. Individual subjects' percent correct. Left Hemisphere. Data collapsed across Hands and Trials. Stimulus durations increase in 1ms steps. S = Square. D = Diamond.

Stimulus duration		1		2		3		4	
Shape		S	D	S	D	S	D	S	D
Subj.	Sex								
601	M	100	50	100	20	100	60	100	50
602	M	100	100	90	90	100	100	100	90
603	M	100	70	90	50	100	90	100	70
604	M	90	50	90	40	100	40	100	70
605	M	100	50	90	40	100	70	100	70
606	M	100	80	100	70	100	80	100	60
607	M	80	60	70	100	100	100	100	80
608	M	90	80	100	60	100	70	100	60
609	F	100	100	90	90	100	90	70	100
610	F	100	90	100	60	80	60	100	70
611	F	100	40	100	40	100	100	100	70
612	F	90	70	60	80	70	90	50	70
613	F	100	20	100	70	90	70	100	60
614	F	90	90	90	70	90	70	80	90
615	F	80	80	90	80	100	80	100	90
616	F	80	80	90	90	100	90	90	80
Mean		93.75	69.38	90.63	65.63	95.63	78.75	93.13	73.75
SD		8.06	22.65	11.24	22.79	8.92	17.08	14.48	13.60

Table 6b.

Experiment Six data. Individual subjects' percent correct. Right Hemisphere. Data collapsed across Hands and Trials. Stimulus durations increase in 1ms steps. S = Square. D = Diamond.

APPENDIX D

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	PROB. F EXCEEDED
MEAN	16692.92773	1	16692.92773	895.66576	.000
S (Sex)	3.15616	1	3.15616	.16934	.686
ERROR	335.47414	18	18.63745		
H (Hemisphere)	1.50975	1	1.50975	.57112	.460
HS	2.40471	1	2.40471	.90966	.353
ERROR	47.58326	18	2.64351		
T (Trial)	58.08935	1	58.08935	11.17252	.004
TS	.87990	1	.87990	.16923	.686
ERROR	93.56755	18	5.19931		
HT	16.20900	1	16.20900	8.64949	.009
HTS	3.54903	1	3.54903	1.89384	.186
ERROR	33.73169	18	1.87398		
H (Hand)	.03444	1	.03444	.00467	.946
HS	19.94004	1	19.94004	2.70399	.117
ERROR	132.73734	18	7.37430		
HH	.21632	1	.21632	.07319	.790
HHS	.15842	1	.15842	.05360	.820
ERROR	53.19801	18	2.95544		

ANOVA Summary Table for Contrast Scores, Experiment One.

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	PROB. F EXCEEDED
MEAN	456469.05469	1	456469.05469	1657.53317	.000
S (Sex)	87.89090	1	87.89090	.31915	.583
O	47.26550	1	47.26550	.17163	.686
SO	722.26569	1	722.26569	2.62270	.131
ERROR	3304.68719	12	275.39060		
B (Hemisphere)	862.89056	1	862.89056	6.21087	.028
BS	112.89061	1	112.89061	.81256	.385
BO	47.26563	1	47.26563	.34021	.571
BSO	141.01562	1	141.01562	1.01500	.334
ERROR	1667.18735	12	138.93228		
H (Hand)	19.14063	1	19.14063	.20332	.660
HS	141.01561	1	141.01561	1.49793	.244
HO (Trials)	141.01561	1	141.01561	1.49793	.244
HSO	425.39059	1	425.39059	4.51867	.055
ERROR	1129.68742	12	94.14062		
BH	31.64062	1	31.64062	.50311	.492
BHS	47.26563	1	47.26563	.75155	.403
BHO	9.76563	1	9.76563	.15528	.700
BHSO	112.89061	1	112.89061	1.79503	.205
ERROR	754.68746	12	62.89062		

ANOVA Summary Table for Percent Correct Scores, Experiment Two

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	PROB. F EXCEEDED
MEAN	3949550.87500	1	3949550.87500	1112.05023	.000
ERROR	53273.90869	15	3551.59390		
T (Trials)	12511.38965	2	6255.69482	9.60155	.001
ERROR	19545.89551	30	651.52985		
H (Hand)	293.78247	1	293.78247	.28146	.604
ERROR	15656.73682	15	1043.78244		
TH	1446.93970	2	723.46985	.92048	.409
ERROR	23579.09985	30	785.96999		
B (Hemisphere)	13125.81250	1	13125.81250	4.35393	.054
ERROR	45220.53418	15	3014.70227		
TB	1144.20508	2	572.10254	.44559	.645
ERROR	38517.25000	30	1283.90833		
HB	1504.71973	1	1504.71973	1.03338	.325
ERROR	21841.63184	15	1456.10878		
THB	1176.50244	2	586.75122	.88481	.423
ERROR	19894.20410	30	663.14014		

ANOVA Summary Table for Percent Correct Scores, Experiment Three.

Analysis one, all subjects, sex not entered as a variable. Page One.

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	PROB. F EXCEEDED
C (Conditions)	13049.31421	3	4349.77136	10.04322	.000
ERROR	19489.74292	45	433.10540		
TC	1752.92773	6	292.15462	.50042	.807
ERROR	52543.93848	90	583.82153		
HC	67.54517	3	22.51506	.03895	.990
ERROR	26013.17969	45	578.07066		
THC	1424.15234	6	237.35872	.54969	.769
ERROR	38862.29980	90	431.80333		
BC	2144.36792	3	714.78931	1.20250	.320
ERROR	26748.85693	45	594.41904		
TBC	3580.53223	6	563.42204	.88864	.507
ERROR	57062.16699	90	634.02407		
HBC	666.50366	3	222.16789	.45492	.715
ERROR	21976.72266	45	488.37161		
THBC	1801.75586	6	300.29264	.51128	.798
ERROR	52859.69385	90	587.32993		

ANOVA Summary Table for Percent Correct Scores, Experiment Three.
Analysis one, all subjects, sex not entered as a variable. Page Two.

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	PROB. F EXCEEDED
MEAN	3163580.25000	1	3163580.25000	1106.56287	.000
J (Sex)	13248.95850	1	13248.95850	4.63424	.049
ERROR	40024.95020	14	2858.92499		
T (Trials)	12386.60620	2	6193.30310	9.28197	.001
TJ	863.17256	2	431.58618	.64662	.531
ERROR	18682.72314	28	667.24011		
H (Hand)	6.78162	1	6.78162	.00658	.937
HJ	1217.71899	1	1217.71899	1.18069	.296
ERROR	14439.01762	14	1031.35841		
TH	716.68799	2	358.34399	.42862	.656
THJ	169.81299	2	84.90649	.10156	.904
ERROR	23409.26662	28	836.04594		
B (Hemisphere)	4655.21875	1	4655.21875	1.57502	.230
BJ	3841.41650	1	3841.41650	1.29969	.273
ERROR	41379.11700	14	2955.65125		
TB	869.68262	2	434.84131	.32202	.727
TBJ	706.92256	2	353.46118	.26175	.772
ERROR	37810.52715	28	1350.36682		
HB	1217.71899	1	1217.71899	.78077	.392
HBJ	6.78149	1	6.78149	.00435	.948
ERROR	21834.05034	14	1559.63216		
THB	775.28174	2	387.64087	.54811	.584
THBJ	91.68823	2	45.84412	.06462	.937
ERROR	19802.51567	28	707.23270		

ANOVA Summary Table for Percent Correct Scores, Experiment Three.
Analysis two, all subjects. Sex entered as a variable. Page One.

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	PROB. F EXCEEDED
C (Conditions)	15654.02197	3	5218.00732	14.25065	.000
CJ	4111.05542	3	1370.35181	3.74250	.018
ERROR	15370.66726	42	366.15922		
TC	2151.14844	6	358.52474	.58538	.741
TCJ	1096.46143	6	182.74357	.29837	.936
ERROR	51447.47607	84	612.46995		
HC	504.28569	3	168.09529	.30563	.821
HCJ	2913.13940	3	971.04646	1.76554	.168
ERROR	23100.04004	42	550.00095		
THC	2792.42480	6	465.40413	1.07376	.385
THCJ	2453.68330	6	408.96055	.94358	.469
ERROR	36408.41602	84	433.43352		
LC	1867.13257	3	622.37752	.98292	.410
LCJ	154.89331	3	51.63110	.08154	.970
ERROR	26590.96338	42	633.16960		
TLC	3242.72852	6	540.45475	.84773	.537
TLCJ	3509.65576	6	584.94263	.91751	.487
ERROR	53552.51025	84	637.52968		
HLC	1051.16064	3	350.38688	.68660	.565
HLCJ	543.34814	3	181.11605	.35491	.786
ERROR	21430.37427	42	510.31843		
THLC	2655.70605	6	442.61768	.75677	.606
THLCJ	3729.92432	6	621.65405	1.06268	.391
ERROR	49129.76855	84	584.87820		

ANOVA Summary Table for Percent Correct Scores, Experiment Three.
Analysis two, all subjects. Sex entered as a variable. Page Two.

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	PROB. F EXCEEDED
MEAN	2767370.40625	1	2767370.40625	825.25370	.000
ERROR	36886.92871	11	3353.35715		
T (Trials)	6812.06372	2	3406.03186	4.75279	.019
ERROR	15766.05701	22	716.63895		
H (Hand)	1042.75159	1	1042.75159	1.02086	.334
ERROR	11235.89319	11	1021.44483		
TH	1538.62817	2	769.31409	.83118	.449
ERROR	20362.41138	22	925.56415		
B (Hemisphere)	16954.20850	1	16954.20850	7.07334	.022
ERROR	26366.09961	11	2396.91812		
TB	1200.08643	2	600.04321	.44509	.646
ERROR	29859.26564	22	1348.14934		
HB	1042.75171	1	1042.75171	.73970	.408
ERROR	15506.72595	11	1409.70235		
THB	1030.81567	2	515.40784	.67673	.519
ERROR	16755.64111	22	761.62005		

ANOVA Summary Table for Percent Correct Scores, Experiment Three.

Analysis three, Female Subjects. Page One.

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	PROB. F EXCEEDED
C (Conditions)	5975.47656	3	1991.82552	4.99769	.006
ERROR	13152.12512	33	398.54924		
TC	1026.47461	6	171.07910	.24896	.958
ERROR	45555.72656	66	687.17767		
HC	1053.60229	3	351.20076	.57200	.637
ERROR	20261.49876	33	613.98481		
THC	570.74585	6	95.12431	.22806	.966
ERROR	27528.20874	66	417.09407		
bC	1426.86572	3	475.62191	.99834	.406
ERROR	15721.56934	33	476.41119		
TbC	3562.89795	6	597.14966	.90223	.499
ERROR	43682.72021	66	661.85959		
HbC	220.26904	3	73.42301	.12020	.948
ERROR	20157.33252	33	610.82825		
ThbC	1911.89062	6	318.64844	.47294	.826
ERROR	44468.31055	66	673.76228		

ANOVA Summary Table for Percent Correct Scores, Experiment Three.

Analysis three, Female Subjects. Page Two.

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	PROB. F EXCEEDED
MEAN	4746275.75000	1	4746275.75000	870.49981	.000
J (Sex)	1647.95117	1	1647.95117	.30225	.591
ERROR	76332.99805	14	5452.35699		
T (Trials)	10415.03760	2	5207.51880	4.69972	.017
TJ	1997.06982	2	998.53491	.90116	.418
ERROR	31025.38672	28	1108.04951		
H (Hands)	235.18878	1	235.18878	.44452	.516
HJ	886.23022	1	886.23022	1.67502	.217
ERROR	7407.22571	14	529.08755		
TH	1105.14282	2	552.57141	.76501	.475
THJ	649.41382	2	324.70691	.44954	.642
ERROR	20224.60571	28	722.30734		
B (Hemisphere)	2832.84473	1	2832.84473	1.87338	.193
BJ	358.88647	1	358.88647	.23733	.634
ERROR	21170.24341	14	1512.16023		
TB	1417.64282	2	708.82141	1.05649	.361
TBJ	2504.88232	2	1252.44116	1.86675	.173
ERROR	18785.80396	28	670.92157		
HB	235.18877	1	235.18877	2.08342	.171
HBJ	1504.71982	1	1504.71982	13.32956	.003
ERROR	1580.40338	14	112.88596		
THB	831.70544	2	415.85272	1.04438	.365
THBJ	831.70557	2	415.85278	1.04438	.365
ERROR	11149.08643	28	398.18166		

ANOVA Summary Table for Percent Correct Scores, Experiment Four.

Analysis one. All conditions. Page One.

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	PROB. F EXCEEDED
C (ISI type)	50456.53271	1	50456.53271	50.05270	.000
CJ	782.06384	1	782.06384	.77580	.393
ERROR	14112.95325	14	1008.06808		
TC	4692.38196	2	2346.19098	7.72922	.002
TCJ	3370.76758	2	1685.38379	5.55228	.009
ERROR	8499.34729	28	303.54811		
HC	430.50122	1	430.50122	.67932	.424
HCJ	7.32410	1	7.32410	.01156	.916
ERROR	8872.06885	14	633.71920		
THC	773.11169	2	386.55585	1.27248	.296
THCJ	825.19507	2	412.59753	1.35821	.274
ERROR	8505.85815	28	303.78065		
BC	2116.69885	1	2116.69885	4.18071	.060
BCJ	.81378	1	.81378	.00161	.969
ERROR	7088.21484	14	506.30106		
TBC	1098.63257	2	549.31628	1.15497	.330
TBCJ	167.64307	2	83.82153	.17624	.839
ERROR	13317.05493	28	475.60910		
HBC	508.62622	1	508.62622	.54859	.471
HBCJ	1237.79272	1	1237.79272	1.33505	.267
ERROR	12980.14099	14	927.15292		
THBC	226.23694	2	113.11847	.31176	.735
THBCJ	1176.75769	2	588.37885	1.62160	.216
ERROR	10159.50366	28	362.83942		
I (ISI duration)	8633.62439	1	8633.62439	23.59803	.000
IJ	293.78241	1	293.78241	.80299	.385
ERROR	5122.06952	14	365.86211		

ANOVA Summary Table for Percent Correct Scores, Experiment Four.

Analysis one. All conditions. Page Two.

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	PROB. F EXCEEDED
TI	372.72119	2	186.36060	.44565	.645
TIJ	157.87744	2	78.93872	.18877	.829
ERROR	11708.98267	28	418.17795		
HI	39.87628	1	39.87628	.07124	.793
HIJ	1797.68848	1	1797.68848	3.21142	.095
ERROR	7836.91296	14	559.77950		
THI	353.18994	2	176.59497	.32772	.723
THIJ	1173.50232	2	586.75116	1.08889	.350
ERROR	15067.88843	28	538.85316		
BI	39.87628	1	39.87628	.08409	.776
BIJ	183.10541	1	183.10541	.38612	.544
ERROR	6638.99615	14	474.21401		
TBI	1505.53357	2	752.76678	1.82652	.180
TBIJ	1069.33569	2	534.66785	1.29732	.289
ERROR	11539.71179	28	412.13256		
HBI	7.32416	1	7.32416	.01636	.900
HBIJ	65.91791	1	65.91791	.14723	.707
ERROR	6267.90259	14	447.70732		
THBI	444.33569	2	222.16785	.61035	.550
THBIJ	1499.02295	2	749.51147	2.05909	.146
ERROR	10192.05579	28	364.00199		
CI	6159.66669	1	6159.66669	44.48614	.000
CIJ	65.91798	1	65.91798	.47607	.501
ERROR	1938.47623	14	138.46259		

ANOVA Summary Table for Percent Correct Scores, Experiment Four.

Analysis one. All conditions. Page Three.

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	PROB. F EXCEEDED
TCI	327.14819	2	163.57410	.50376	.610
TCIJ	1674.80432	2	837.40216	2.57895	.094
ERROR	9091.79553	28	324.70698		
HCI	235.18872	1	235.18872	.55653	.468
HCIJ	2116.69897	1	2116.69897	5.00880	.042
ERROR	5916.34021	14	422.59573		
THCI	489.90875	2	244.95438	1.08441	.352
THCIJ	737.30444	2	368.65222	1.63201	.214
ERROR	6324.86871	28	225.88817		
BCI	183.10541	1	183.10541	.53444	.477
BCIJ	996.90735	1	996.90735	2.90974	.110
ERROR	4796.54865	14	342.61061		
TBCI	131.83582	2	65.91791	.17053	.844
TBCIJ	763.34619	2	381.67310	.98737	.385
ERROR	10823.56604	28	386.55593		
HBCI	684.40735	1	684.40735	1.15909	.300
HBCIJ	358.88660	1	358.88660	.60780	.449
ERROR	8266.60010	14	590.47144		
THBCI	450.84625	2	225.42313	1.45243	.251
THBCIJ	151.36713	2	75.68356	.48764	.619
ERROR	4345.70245	28	155.20366		

ANOVA Summary Table for Percent Correct Scores.Experiment Four.

Analysis one. All conditions. Page Four.

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	PROB. F EXCEEDED
MEAN	1908998.65625	1	1908998.65625	424.01605	.000
J (Sex)	79.75293	1	79.75293	.01771	.896
ERROR	63030.58887	14	4502.18488		
T (Trials)	14365.23193	2	7182.61597	8.13135	.002
TJ	5276.69165	2	2638.34583	2.98684	.067
ERROR	24733.06885	28	883.32388		
H (Hands)	14.64832	1	14.64832	.01957	.891
HJ	366.21082	1	366.21082	.48928	.496
ERROR	10478.51392	14	748.46528		
TH	1240.23389	2	620.11694	.87242	.429
THJ	1357.42139	2	678.71069	.95486	.397
ERROR	19902.34106	28	710.79789		
B (Hemisphere)	4923.50195	1	4923.50195	5.33241	.037
BJ	196.94006	1	196.94006	.21330	.651
ERROR	12926.43054	14	923.31647		
TB	159.50513	2	79.75256	.22882	.797
TBJ	706.38000	2	353.19000	1.01334	.376
ERROR	9759.11328	28	348.53976		
HB	717.77332	1	717.77332	1.09507	.313
HBJ	2736.00220	1	2736.00220	4.17418	.060
ERROR	9176.43091	14	655.45935		
THB	888.67163	2	444.33582	.91304	.413
THBJ	1526.69250	2	763.34625	1.56856	.226
ERROR	13626.30042	28	486.65358		

ANOVA Summary Table for Percent Correct Scores, Experiment Four.

Analysis two, Conditions 1 and 2 (intermittent background field). Page One.

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	PROB. F EXCEEDED
C (Conditions)	14689.12476	1	14689.12476	41.26388	.000
CJ	40.69000	1	40.69000	.11430	.740
ERROR	4983.72333	14	355.98024		
TC	61.84875	2	30.92438	.06775	.935
TCJ	804.03625	2	402.01813	.88079	.426
ERROR	12779.94641	28	456.42665		
HC	40.69006	1	40.69006	.06723	.799
HCJ	3907.87695	1	3907.87695	6.45678	.024
ERROR	8473.30615	14	605.23615		
THC	804.03638	2	402.01819	.97080	.391
THCJ	1665.41125	2	831.70563	2.00842	.153
ERROR	11595.05054	28	414.10895		
BC	196.94006	1	196.94006	.32047	.580
BCJ	1017.25244	1	1017.25244	1.65532	.219
ERROR	8603.51428	14	614.53673		
TBC	452.47388	2	226.23694	.47907	.624
TBCJ	804.03625	2	402.01813	.85130	.438
ERROR	13222.65454	28	472.23766		
HBC	275.06506	1	275.06506	.36211	.557
HBCJ	366.21082	1	366.21082	.48209	.499
ERROR	10634.76416	14	759.62601		
THBC	882.16138	2	441.08069	1.45364	.251
THBCJ	1142.57788	2	571.28894	1.88276	.171
ERROR	8496.09253	28	303.43187		

ANOVA Summary Table for Percent Correct Scores, Experiment Four.

Analysis two, Conditions 1 and 2 (intermittent background field). Page Two.

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	PROB. F EXCEEDED
MEAN	2101601.96875	1	2101601.96875	342.40250	.000
J (Sex)	137.53223	1	137.53223	.02241	.883
ERROR	85929.35937	14	6137.81134		
T (Trials)	23409.82910	2	11704.91455	13.62948	.000
TJ	7648.11084	2	3824.05542	4.45282	.021
ERROR	24046.22144	28	858.79362		
H (Hands)	.81378	1	.81378	.00151	.970
HJ	2644.04272	1	2644.04272	4.91953	.044
ERROR	7524.41345	14	537.45810		
TH	167.64319	2	83.82159	.16818	.846
THJ	981.44507	2	490.72253	.98460	.386
ERROR	13955.07678	28	498.39560		
B (Hemisphere)	11914.87598	1	11914.87598	2.30728	.151
BJ	14395.34375	1	14395.34375	2.78761	.117
ERROR	72296.54004	14	5164.03857		
TB	1339.51807	2	669.75903	1.68994	.203
TBJ	6105.14282	2	3052.57141	7.70226	.002
ERROR	11097.00427	28	396.32158		
HB	358.88666	1	358.88666	.81602	.382
HBJ	7.32422	1	7.32422	.01665	.899
ERROR	6157.22589	14	439.80185		
THB	825.19507	2	412.59753	.58710	.563
THBJ	3872.06982	2	1936.03491	2.75484	.081
ERROR	19677.73291	28	702.77617		

ANOVA Summary Table for Percent "Space" Responses, Experiment Five. Page One.

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	PROB. F EXCEEDED
C (Condition)	149455.53711	3	49818.51221	23.66244	.000
CJ	5751.13770	3	1917.04590	.91054	.444
ERROR	88426.09375	42	2105.38318		
TC	3471.67773	6	578.61295	.67460	.670
TCJ	3855.79199	6	642.63200	.74924	.612
ERROR	72047.51660	84	857.70853		
HC	3531.08618	3	1177.02872	2.14181	.109
HCJ	2854.00293	3	951.33430	1.73112	.175
ERROR	23081.05176	42	549.54885		
THC	2208.65723	6	368.10954	.75768	.605
THCJ	11147.45801	6	1857.90967	3.82412	.002
ERROR	40810.54150	84	485.83978		
BC	952.96191	3	317.65397	.42163	.738
BCJ	1975.09717	3	658.36572	.87387	.462
ERROR	31642.24854	42	753.38686		
TBC	4474.28223	6	745.71370	1.47852	.195
TBCJ	5346.67822	6	891.11304	1.76681	.116
ERROR	42366.53174	84	504.36347		
HBC	4409.99268	3	1469.99756	2.63186	.062
HBCJ	2118.32666	3	706.10889	1.26421	.299
ERROR	23458.65552	42	558.53941		
THBC	4259.43848	6	709.90641	1.34195	.248
THBCJ	4949.54248	6	824.92374	1.55937	.169
ERROR	44436.84326	84	529.01003		

ANOVA Summary Table for Percent "Space" Responses, Experiment Five. Page Two.

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	PROB. F EXCEEDED
MEAN	9978149.00000	1	9978149.00000	1951.34743	.000
J (Sex)	1666.66113	1	1666.66113	.32594	.577
ERROR	71588.52637	14	5113.46613		
R (Trials)	6341.14209	2	3170.57104	2.56992	.094
RJ	1614.58301	2	807.29150	.65435	.528
ERROR	34544.26416	28	1233.72371		
S (Hands)	234.37488	1	234.37488	.24561	.628
SJ	416.66638	1	416.66638	.43665	.519
ERROR	13359.37256	14	954.24089		
RS	1406.24951	2	703.12476	.45202	.641
RSJ	872.39502	2	436.19751	.28042	.758
ERROR	43554.67969	28	1555.52426		
T (Hemisphere)	2350.25977	1	2350.25977	.50958	.487
TJ	1881.50977	1	1881.50977	.40795	.533
ERROR	64570.29980	14	4612.16425		
RT	950.52051	2	475.26025	.49660	.614
RTJ	169.27075	2	84.63538	.08844	.916
ERROR	26796.87134	28	957.03111		
ST	1881.51025	1	1881.51025	1.54782	.234
STJ	1881.51001	1	1881.51001	1.54782	.234
ERROR	17018.22583	14	1215.58755		
RST	403.64563	2	201.82281	.53713	.590
RSTJ	2825.52039	2	1412.76019	3.75990	.036
ERROR	10520.83142	28	375.74398		

ANOVA Summary Table for Percent Correct Responses, Experiment Six. Page One.

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	PROB. F EXCEEDED
U (Condition)	8398.43604	3	2799.47867	2.98809	.042
UJ	1888.02002	3	629.34000	.67174	.574
ERROR	39348.95264	42	936.87982		
RU	4101.56055	6	683.59342	.96351	.455
RUJ	5260.41504	6	876.73584	1.23574	.296
ERROR	59596.34570	84	709.48030		
SU	7903.64453	3	2634.54816	3.14043	.035
SUJ	559.89502	3	186.63167	.22247	.880
ERROR	35234.37012	42	838.91357		
RSU	2057.29004	6	342.88167	.39408	.881
RSUJ	3815.10254	6	635.85042	.73080	.626
ERROR	73085.92676	84	870.07056		
TU	5371.09326	3	1790.36441	1.99069	.130
TUJ	5345.05127	3	1781.68375	1.98104	.131
ERROR	37773.43164	42	899.36742		
RTU	5273.43457	6	878.90576	1.09629	.371
RTUJ	3424.47656	6	570.74609	.71191	.641
ERROR	67343.74023	84	801.71119		
STU	813.80127	3	271.26709	.26571	.850
STUJ	4485.67578	3	1495.22525	1.46462	.238
ERROR	42877.59668	42	1020.89516		
RSTU	4205.72559	6	700.95426	.85676	.530
RSTUJ	8111.97656	6	1351.99609	1.65252	.143
ERROR	68723.94629	84	818.14221		

ANOVA Summary Table for Percent Correct Responses, Experiment Six. Page Two.

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	PROB. F EXCEEDED
V (Shape)	136881.48437	1	136881.48437	42.89566	.000
VJ	787.76025	1	787.76025	.24687	.627
ERROR	44674.47217	14	3191.03372		
RV	1028.64502	2	514.32251	.41548	.664
RVJ	247.39502	2	123.69751	.09992	.905
ERROR	34661.45361	28	1237.90906		
SV	58.59363	1	58.59363	.08389	.776
SVJ	527.34363	1	527.34363	.75499	.400
ERROR	9778.64453	14	698.47461		
RSV	1445.31201	2	722.65601	.77468	.470
RSVJ	1914.06201	2	957.03101	1.02592	.372
ERROR	26119.78809	28	932.84957		
TV	5104.16602	1	5104.16602	.42922	.523
TVJ	28359.36914	1	28359.36914	2.38480	.145
ERROR	166484.34570	14	11891.73889		
RTV	1341.14551	2	670.57275	.50122	.611
RTVJ	468.74951	2	234.37476	.17518	.840
ERROR	37460.93164	28	1337.89041		
STV	1276.04150	1	1276.04150	.74809	.402
STVJ	2604.16626	1	2604.16626	1.52672	.237
ERROR	23880.20459	14	1705.72890		

ANOVA Summary Table for Percent Correct Responses, Experiment Six. Page Three.

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	PROB. F EXCEEDED
RSTV	2708.33252	2	1354.16626	1.16713	.326
RSTVJ	2200.52002	2	1100.26001	.94830	.399
ERROR	32486.97461	28	1160.24908		
UV	3834.63428	3	1278.21143	1.13613	.345
UVJ	110.67676	3	36.89225	.03279	.992
ERROR	47252.59619	42	1125.06181		
RUV	8372.39355	6	1395.39893	1.90720	.089
RUVJ	1940.10205	6	323.35034	.44195	.849
ERROR	61458.32471	84	731.64672		
SUV	214.84351	3	71.61450	.12548	.945
SUVJ	1490.88477	3	496.96159	.87072	.464
ERROR	23971.35059	42	570.74644		
RSUV	3007.80957	6	501.30159	.55990	.761
RSUVJ	5013.01758	6	835.50293	.93317	.476
ERROR	75208.32031	84	895.33714		
TUV	2669.27051	3	889.75684	.91111	.444
TUVJ	2825.52002	3	941.84000	.96444	.418
ERROR	41015.61865	42	976.56235		
RTUV	1861.97754	6	310.32959	.42915	.858
RTUVJ	1666.66504	6	277.77750	.38414	.887
ERROR	60742.17871	84	723.12117		
STUV	2981.77051	3	993.92350	1.19538	.323
STUVJ	1627.60352	3	542.53450	.65250	.586
ERROR	34921.86914	42	831.47307		
RSTUV	4869.79102	6	811.63184	1.23520	.297
RSTUVJ	10247.39307	6	1707.89883	2.59920	.023
ERROR	55195.30420	84	657.08695		

ANOVA Summary Table for Percent Correct Responses, Experiment Six. Page Four.